THE MINDFUL UNIVERSE (Dec. 15, 2004)

PREAMBLE.

This book is about you. It is about your basic nature as a human being. It is about the connection of your mind to your body.

You may think that that your mind---your stream of conscious thoughts, ideas, and feelings---influences your actions. You might believe that what you think affects what you do. You could be right. However, the scientific theories that prevailed from the time of Isaac Newton to the beginning of the twentieth century asserted that your physical actions are completely controlled by purely mechanical processes that are specified without acknowledging or entailing the existence of your mind. According to that earlier form of science, any belief that your conscious choices make a difference in how you behave is an illusion. You were asserted to be, in essence, a mechanical automaton.

We now know that the principles underlying that earlier form of science are fundamentally incorrect. During the first part of the twentieth century those mechanical theories were replaced by a new physical theory that reproduces all of the successful predictions of the prior theories, while also giving valid predictions about phenomena that are incompatible with its predecessors. No prediction of the new theory has been shown to be false.

The new theory differs from the old one in many interesting ways, but none is more important than the new role it gives to conscious choices made by human beings about how they will act. These conscious choices, which are not determined by any mechanically described aspects of the theory, are asserted by the theory to have specific causal effects upon the mechanically described aspects. This causal arrangement breaks the purely mechanical determinism of the earlier theories, and sets up a specific dynamical process that allows your conscious thoughts to influence your physical actions.

Although more than three quarters of a century have passed since the emergence of the new physics, the old idea of mechanical determinism has not yet been rooted out of educated thought. The force of that scientifically unsupported idea continues to have a profound impact upon your life. It still drives the decisions of governments, schools, courts, and medical institutions, and even your own choices, to the extent that you are influenced by what you read and are told by pundits who expound as scientific truth the conclusions of a fundamentally false theory.

The aim of this book is to explain to readers unacquainted with contemporary physics how the twentieth century revolution in atomic science leads to an understanding of human nature that differs profoundly from the mechanical picture promulgated by the science of earlier centuries. The new conception allows your conscious thoughts to play an influential role in the determination of your physical actions.

1. SCIENCE AND HUMAN VALUES.

Science has improved our lives in many ways. It has lightened the load of tedious tasks and expanded our physical powers, thereby contributing to a great flowering of human creative energy. On the other hand, it has also given us the capacity to ravage the environment on an unprecedented scale and to obliterate our species altogether. Yet along with this fatal power it has provided a further offering which, though subtle in character and still hardly felt in the minds of men, may ultimately be its most valuable contribution to human civilization, and the key to human survival.

Science is not only the enterprise of harnessing nature to serve the practical needs of humankind. It is also part of man's unending search for knowledge about the universe and his place within it. This quest is motivated not solely by idle curiosity. Each of us, when trying to establish values upon which to base conduct, is inevitably led to the question of one's place in the greater whole. The linkage of this philosophical inquiry to the practical question of personal values is no mere intellectual abstraction. Martyrs in every age are vivid reminders of the fact that no influence upon human conduct, even the instinct for self preservation, is stronger than beliefs about one's relationship to the power that shapes the universe. Such beliefs form the foundation of a person's self image, and hence, ultimately, of personal values.

It is often claimed that science stands mute on questions of values: that science can help us to achieve what we value once our priorities are fixed, but can play no role in fixing these weightings. That claim is certainly incorrect: science plays a key role in these matters. For what we value depends on what we believe, and what we believe is increasingly determined by science.

A striking example of this influence is the impact of science upon the system of values promulgated by the church during the Middle Ages. That structure rested on a credo about the nature of the universe, its creator, and man's connection to that creator. Science, by casting doubt upon that belief, undermined the system of values erected upon it. Moreover, it put forth a credo of its own. In that "scientific" vision we human beings were converted from sparks of divine creative power, endowed with free will, to automatons---to cogs in a giant machine that grinds inexorably along a preordained path in the grip of a blind mechanical process.

Gone from this "scientific" picture of our species is any rational basis for the notion of a person's responsibility for his own actions. Each of us is asserted to be a mechanical extension of what existed prior to his birth. Over that earlier situation one has no control. Hence for what emerges, preordained, from that prior state one can bear no responsibility.

Given this conception of man the collapse of rational moral philosophy is inevitable. For this notion of the human being provides no rational basis for any value but self interest: behavior promoting the welfare of others, including future generations, becomes rational only to the extent that such behavior serves one's own interests. Hence science becomes doubly culpable: it not only undermines the foundations of earlier value systems, but also strips man of any vision of himself and his place in the universe that could be the rational basis for an elevated set of values.

This mechanical view of nature and of man's place within it dominated science at the end of the nineteenth century. According to that notion, the physical universe is composed of tiny bits of matter, and the unfolding of the observed world over the course of time is completely fixed by the interactions of these tiny localized realities with their immediate neighbors. Human beings, insofar as they are parts of this physically describable reality, are simply conglomerations of these tiny components whose motions are completely fixed by interactions at the atomic level.

During the twentieth century this simple picture of nature was found to be profoundly wrong. It failed not just in its fine details, but at its fundamental core. A vastly different conceptual framework was erected by the atomic physicists Werner Heisenberg, Niels Bohr, Wolfgang Pauli and their colleagues. Those scientists were forced to a wholesale revision of the entire subject matter of physical theory by the strange character of the new mathematical rules, which were invariably validated by reliable empirical data.

The earlier "classical" physics had emerged from the study of the observed motions of the planets and large terrestrial objects. The entire physical universe was then conceived to be made out of miniaturized versions of these large visible objects. Rules were found that appeared to control the behavior of these tiny entities, and the objects composed of them. These laws were completely independent of whether we were observing the physical universe or not: the laws took no special cognizance of any acts of observation performed by human beings, or of any knowledge acquired from such observations. However, the baffling features of new kinds of data acquired during the twentieth century caused the physicists who were studying these phenomena, and trying to ascertain the laws that governed them, to turn the whole scientific enterprise upside down.

Perhaps I should say that they turned what had been upside down rightside up. For the word "science" comes from the Latin scire, "to know," and what the quantum physicists claimed, basically, is that the proper subject matter of science is not what may or may not be "out there," unobserved and unknown to human beings. It is rather what we human beings can know. Thus they formulated their new theory, called quantum theory, around the knowledge-acquiring actions of human beings and the knowledge acquired from these actions, not around some imagined-to-exist world out there. The whole focus of the theory was thus shifted from one that basically ignored our knowledge to one that is essentially about our knowledge.

This shift did not amount merely to looking at the same old physical world from an egocentric point of view. Rather the whole landscape was transformed into something so strange and unfamiliar that it seemed to be understandable only in terms of how it worked for us.

This modified conception of science differs from the old one in many fascinating mathematical ways that continue to excite the interest of physicists. However, it is the revised understanding of the basic nature of human beings, and of the causal role of their consciousness in the unfolding of reality, that is, I believe, the most exciting thing about the new physics, and probably, in the final analysis, the most important contribution of science to the well-being of our species.

The new theory, quantum theory, accounts in a uniform manner for all the observed successes of the earlier physical theories, and also for the immense accumulation of new data for which the earlier methods fail abysmally. But it describes a world built not out of bits of matter, as matter was understood in the nineteenth century, but rather out of a fundamentally different kind of stuff. According to the revised notion, physical reality behaves more like spatially encoded information that governs tendencies for experiential events to occur, than like anything resembling material substance.

Moreover, according to this new understanding, the world is governed not by one single uniform process, but by several very different complementary processes, only one of which is analogous to the mechanical process described by classical physics. The quantum counterpart of the older classical mechanical process is the part of the new theory of main interest to physicists, engineers, and other workers not concerned with the mental side of reality. But anyone interested in the role in nature of our conscious thoughts, ideas, and feelings needs to understand the other processes, because those processes allow our conscious thoughts to affect our physical actions.

Nothing like this action of mind upon the physical body exists in classical physics. Indeed, there is nothing in the principles of classical physics that requires, or even hints at, the existence of such things as thoughts, ideas, and feelings, and certainly no rules that dictate how the idea-like aspects of nature influence the physical aspects. Indeed, it was precisely the absence of any notion of experiential-type realities in classical physics, or of any job for them to do, or of any possibility for them to do anything not already done by the tiny mechanical elements, that has been the bane of philosophy for three hundred years. Now, however, that material conception of nature, which was the cause of so much philosophical dispute, has been found to be fundamentally false. It has been replaced by a radically different framework of ideas that not only reproduces all the verified results of the prior theory, and also the huge wealth of new data, but can also explain how thoughts affect bodily actions. The new theory, unlike the old one, gives our conscious mental efforts an essential role to play in the unfolding of reality. In quantum theory the action of our minds does not just redundantly over-determine things that are already fully determined by the interactions of tiny bits of matter. Rather it fills an otherwise unfilled gap in the dynamical rules. This gap was opened by a principle of uncertainty that lies at the mathematical heart of the new physics.

The original “Copenhagen” formulation of quantum theory is the official doctrine. It is what is used in actual practice. However, it is formulated simply as a set of rules to be used by physicists as they go about their jobs of collecting data and making predictions. It is fundamentally a set of practical rules that allow us to use the knowledge that we obtain by acting upon Nature, and observing her responses to our actions, to compute valid predictions about what the responses to our various possible future actions are likely to be.

There is a huge difference between this new physical theory and the classical physical theory that it supercedes. The older theory was about tiny bits of matter, and how their behaviors were governed by the effects of the neighboring bits. The new theory is about bits of information or knowledge that agents acquire by performing purposeful actions. It is about the freedom provided by the theory for human agents to choose which actions they will take --- and when they will take them --- and about the useful knowledge we can derive from our experiencing of Nature’s responses to our probing actions.

I begin my explanation of these developments in science by emphasizing, in the words of the founders themselves, the central role played in new theory by “our knowledge.”

2. REALITY AS KNOWLEDGE.

What are you made of? What is reality made of? What does intuition say about this? What does science say?

The deliverance of intuition on these matters is not unambiguous. Western science and philosophy begins with Thales of Miletus, who proclaimed "All is Water!” Other Greeks believed the primordial stuff to be "Air", or "Earth", or "Fire", and Empedocles settled on all four. On the other hand, Leucippus and Democritus thought everything was composed of tiny invisible, immutable atoms. Two millennia later, it looked like the two atomists had gotten it right: Isaac Newton built his seventeenth-century theory of the universe on the idea of enduring miniscule particles, and John Dalton's atomic hypothesis explained many facts of chemistry.

This notion that everything is composed of small bits of matter encounters, however, a serious difficulty. The earlier idea that "air" was a primary ingredient allowed soul or spirit to be construed as constructed out of one of the primitive substances. But it was hard to see how such a thing as a sensation of the color "red" or "green", or a feeling of "pain" or "joy" could be fully described in terms of a collection of tiny immutable bits of matter careening through space. Given even supreme knowledge and comprehension, how could the motions of billions of particles in a person's brain/body be understood to produce, or be the very same thing as, a conscious sensation, or the feeling associated with the grasping of an idea? One can understand all manner of motions of objects, and of their changing shapes, in terms of the motions of their constituent parts, but there is a rationally unbridgeable conceptual gap between the purely geometrical concepts of motions of immutable atomic particles in space and the psychological realities of conscious sensations, feelings, ideas, and efforts.

Isaac Newton built his theory upon the ideas of the French philosopher Rene Descartes, who resolved this dilemma concerning the psychological realities by conceiving nature to be built out of two sorts of substances: "matter", which was located in and occupied space, and the "mental stuff" that our ideas, thoughts, sensations, feelings, and efforts are made of. This sundering of nature worked well in science for more than two hundred years, but was abandoned by physicists during the twentieth century. Once it became clear that the old mechanical notions could not account for the growing mountain of data concerning the properties of systems that depend sensitively on the properties of their atomic constituents the theoretical focus shifted from the idea of a material world existing “out there”, independently of our observations of it, to what the experiments were actually telling us. This opened the door to a new approach that dealt directly with our knowledge about the systems being examined, rather than with the supposedly independently existing system itself. An incredibly beautiful and rationally coherent new kind of mathematical structure was eventually created. But this new mathematics described not a self-sufficient physical reality that exists independently of all minds, but rather a radically new kind of physical reality that represents, among other things, the evolving state of our knowledge, and also the effective tendencies, or propensities, for new acts of knowing to occur.

The original and official Copenhagen formulation of quantum theory is closely tied to actual experimental procedures. It is built around the activities of human experimenters who design and perform experiments with some purpose in mind, and who later record and interpret the results of their observations. This formulation has elements that are definitely subjective and even anthropocentric. Other physicists have sought to eliminate these subjective features. But those efforts, some of which I shall describe later, must preserve the connections to human knowledge specified by the founders if they are to retain the empirical content of the theory.

In the introduction to his book "Quantum theory and reality" the philosopher of science Mario Bunge (1967) said:

"The physicist of the latest generation is operationalist all right, but usually he does not know, and refuses to believe, that the original Copenhagen interpretation---which he thinks he supports---was squarely subjectivist, i.e., nonphysical."

Let there be no doubt about this point. The original form of quantum theory is subjective, in the sense that it is forthrightly about relationships among conscious human experiences, and it expressly recommends to scientists that they resist the temptation to try to understand the reality responsible for the correlations between our experiences that the theory correctly describes. The following brief collection of quotations by the founders gives a conspectus of the Copenhagen philosophy:

Heisenberg (1958a): "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behavior."

Heisenberg (1958b): "...the act of registration of the result in the mind of the observer. The discontinuous change in the probability function…takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change of the probability function."

Heisenberg (1958b): "When the old adage `Natura non facit saltus' (Nature makes no jumps) is used as a basis of a criticism of quantum theory, we can reply that certainly our knowledge can change suddenly, and that this fact justifies the use of the term `quantum jump'. "

Wigner (1961): "the laws of quantum mechanics cannot be formulated...without recourse to the concept of consciousness."

Bohr (1934): "In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of our experience."

Bohr (1963): "Strictly speaking, the mathematical formalism of quantum mechanics merely offers rules of calculation for the deduction of expectations about observations obtained under well-defined classical concepts."

Bohr (1958): "...the appropriate physical interpretation of the symbolic quantum mechanical formalism amounts only to prediction of determinate or statistical character, pertaining to individual phenomena appearing under conditions defined by classical physics concepts."

The references to "classical (physics) concepts" is explained in Bohr (1958): "...it is imperative to realize that in every account of physical experience one must describe both experimental conditions and observations by the same means of communication as the one used in classical physics."

Bohr (1958) "...we must recognize above all that, even when phenomena transcend the scope of classical physical theories, the account of the experimental arrangement and the recording of observations must be given in plain language supplemented by technical physical terminology."

Bohr is saying that scientists do in fact use, and must use, the concepts of classical physics in communicating to their colleagues the specifications on how the experiment is to be set up, and what will constitute a certain type of outcome. He in no way claims or admits that there is an actual objective reality out there that conforms to the precepts of classical physics.

In his book "The creation of quantum mechanics and the Bohr-Pauli dialogue" (Hendry, 1984) the historian John Hendry gives a detailed account of the fierce struggles by such eminent thinkers as Hilbert, Jordan, Weyl, von Neumann, Born, Einstein, Sommerfeld, Pauli, Heisenberg, Schroedinger, Dirac, Bohr and others, to come up with a rational way of comprehending the data from atomic experiments. Each man had his own bias and intuitions, but in spite of intense effort no rational comprehension was forthcoming. Finally, at the 1927 Solvay conference a group including Bohr, Heisenberg, Pauli, Dirac, and Born come into concordance on a solution that came to be called "The Copenhagen Interpretation", due to the central role of Bohr and those working with him at his institute in Denmark.

Hendry says: "Dirac, in discussion, insisted on the restriction of the theory's application to our knowledge of a system, and on its lack of ontological content." Hendry summarized the concordance by saying: "On this interpretation it was agreed that, as Dirac explained, the wave function represented our knowledge of the system, and the reduced wave packets our more precise knowledge after measurement."

These quotations make it clear that, in direct contrast to the ideas of classical physical theory, quantum theory is about “our knowledge.” We, and in particular our mental aspects, have entered into the structure of basic physical theory.

This profound shift in physicists’ conception of the basic nature of their endeavor, and of the meanings of their formulas, was not a frivolous move: it was a last resort. The very idea that in order to comprehend atomic phenomena one must abandon physical ontology, and construe the mathematical formulas to be directly about the knowledge of human observers, rather than about the external real events themselves, is so seemingly preposterous that no group of eminent and renowned scientists would ever embrace it except as an extreme last measure. Consequently, it would be frivolous of us simply to ignore a conclusion so hard won and profound, and of such apparent direct bearing on our effort to understand the connection of our conscious thoughts to our bodily actions.

Einstein never accepted the Copenhagen interpretation. He said: "What does not satisfy me, from the standpoint of principle, is its attitude toward what seems to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)." (Einstein, 1951, p.667: the parenthetical word and phrase are part of Einstein's statement.);

and "What I dislike in this kind of argumentation is the basic positivistic attitude, which from my view is untenable, and which seems to me to come to the same thing as Berkeley's principle, esse est percipi. (Einstein, 1951, p. 669). [Transl: To be is to be perceived]

Einstein struggled until the end of his life to get the observer's knowledge back out of physics. But he did not succeed! Rather he admitted that: "It is my opinion that the contemporary quantum theory constitutes an optimum formulation of the [statistical] connections." (ibid. p. 87).

He also referred to: "the most successful physical theory of our period, viz., the statistical quantum theory which, about twenty-five years ago took on a logically consistent form. This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events." (ibid p. 81).

One can adopt the cavalier attitude that these profound difficulties with the classical conception of nature are just some temporary retrograde aberration in the forward march of science: one may imagine, as some do, that a strange confusion has confounded our best minds for seven decades, and that the weird conclusions of physicists can be ignored because they do not fit our classical-physics-based intuitions. Or one can try to claim that these problems concern only atoms and molecules, but not the big things built out of them. In this connection Einstein said: "But the `macroscopic' and `microscopic' are so inter-related that it appears impracticable to give up this program [of basing physics on the `real'] in the `microscopic' domain alone." (ibid, p.674).

The quotations displayed above make clear the fact that Copenhagen quantum theory brings human consciousness into the theory in an essential way. The questions before us are these: How is this done? And how does this radical change in basic physics affect science's conception of the human person?

The principal question here concerns the causal role of our minds in the determination of our actions: Are our physical actions completely controlled by mechanical processes that are fully specified by short-range interactions between tiny localized mechanical parts, or, on the other hand, are our actions influenced, irreducibly, by psychological realities? Are the activities of our brains completely determined by “bottom-up” processes---i.e., by contact interactions between tiny material elements—or can there be also an essential “top-down” contribution: an effect of conscious mental activity, per se, that influences brain action in a way that is not a consequence of microscopic bottom-up processes alone?

According to quantum theory the answer to this final question is “Yes”! The immediate follow-up question is then: How can something having the character of an experiential or conscious reality enter rationally into the mathematical structure that describes the physical state of the brain? How does quantum theory resolve the core problem of philosophy, which is the apparent logical disconnect between our concept of mind and our scientific understanding of the nature of the physical world?

The answer, in brief, is this: Quantum theory is constructed by replacing the “numbers” that describe the material world of classical physics by “actions”, and in this world of actions the psychological and physical aspects of reality are entities of the same kind, linked by mathematical laws! My aim here is to explain to non physicists, in a lucid but technically accurate manner, how the dynamical bonding of these apparently disparate realities is achieved.

3. ACTIONS AND INFORMATION.

The Anti-Newtonian Revolution

From the time of Isaac Newton to the beginning of the twentieth century science relegated consciousness to the role of passive viewer: our thoughts, ideas, and feelings were treated as impotent bystanders to a march of events wholly controlled by contact interactions between tiny mechanical elements. Conscious experiences, insofar as they had any influences at all on what happens in the physical world, were thought to be completely determined at the microscopic level by the motions of miniscule entities. Hence the experiential felt realities that make up our streams of consciousness were regarded as either irrelevant to physics or redundant, and were denied fundamental status in the basic theory of physics.

The founders of quantum mechanics made the revolutionary move of bringing conscious human experiences into basic physical theory in a fundamental way. In the words of Niels Bohr, the key innovation was to recognize that "in the great drama of existence we ourselves are both actors and spectators." (Bohr, 1963, p. 15: 1958, p. 81) After two hundred years of neglect, our thoughts were suddenly thrust into the limelight. This was an astonishing reversal of precedent because the enormous successes of the prior physics were due in large measure to the policy of excluding all mention of idea-like qualities from the formulation of the physical laws.

What sort of crisis could have forced the creators of quantum theory to make this radical innovation of injecting mind explicitly into the basic laws of physics? The answer to this question begins with a discovery that occurred at the beginning of the twentieth century. In the year 1900 Max Planck discovered and measured the "quantum of action." Its measured value is called "Planck's Constant." This constant specifies one of three basic quantities that are built into the fundamental fabric of the physical universe. The other two are the gravitational constant, which fixes the strength of the force that pulls every bit of matter in the universe toward every other bit, and the speed of light, which controls the response of every particle to this force, and to every other force. The integration into physics of each of these three basic quantities generated a monumental shift in our conception of nature.

Isaac Newton discovered the gravitational constant, which linked our understandings of celestial and terrestrial dynamics. It connected the motions of the planets and their moons to the trajectories of cannon balls here on earth, and to the rising and falling of the tides. Insofar as his laws are complete the entire physical universe is governed by mathematical equations that link every bit of matter to every other bit, and moreover fix the complete course of history for all times from physical conditions prevailing in the primordial past.

Einstein recognized that the "speed of light" is not just the rate of propagation of some special kind of wave-like disturbance, namely "light". It is rather a fundamental number that enters into the equations of motion of every kind of material substance, and, among other things, prevents any piece of matter from traveling faster than this universal maximum value. Like Newton's gravitational constant it is a number that enters ubiquitously into the basic structure of Nature.

But important as the effects of these two quantities are, they are, in terms of profundity, like child's play compared to the consequences of Planck's discovery.

Planck's "quantum of action" revealed itself first in the study of light, or, more generally, of electromagnetic radiation. The radiant energy emerging from a tiny hole in a heated hollow container can be decomposed into its various frequency components. Classical nineteenth century physics gave a clean prediction about how that energy should be distributed among the frequencies, but the empirical facts did not fit that theory. Eventually, Planck discovered that the empirically correct formula could be obtained by assuming that the energy was concentrated in finite packets, with the amount of energy in each such unit being directly proportional to the frequency of the radiation that was carrying it. The ratio of energy to frequency is called "Planck's constant". Its value is extremely small on the scale of normal human activity, but becomes significant when we come to the behavior of the atomic particles and fields out of which our bodies, brains, and all large physical objects are made.

Planck's discovery shattered the classical laws that had been the foundation of the scientific world view. During the years that followed many experiments were performed on systems whose behavior depends sensitively upon the properties of their atomic constituents and it was repeatedly found that the classical principles did not work: they gave well defined predictions that turned out to be flat-out wrong when confronted with the experimental evidence. The fundamental laws of physics that every physics student had been taught, and upon which much of the industrial and technological world of that era was based, were not correct. But more importantly, and surprisingly, they failed in a way that no mere tinkering could ever fix. Something was fundamentally amiss. No one could say how these laws, which were so important, and that had seemed so perfect, could be fixed. No one could foresee whether a new theory could be constructed that would explain these strange and unexpected results, and restore rational order to our understanding of the cosmos. But one thing was clear to those working feverishly on the problem: Planck's constant was somehow at the center of it all.

The World of Actions

Werner Heisenberg was, from a technical point of view, the principal founder of quantum theory. He discovered in 1925 the completely amazing and wholly unprecedented solution to the puzzle: the quantities that classical physical theory was based upon, and which were thought to be numbers, must be treated not as numbers but as actions! Ordinary numbers, such as 2 and 3, have the property that the product of any two of them does not depend on the order of the factors: 2 times 3 is the same as 3 times 2. But Heisenberg discovered that one could get the correct answers out of the old classical laws if one decreed that certain of the numbers that are used in classical physics to describe the properties of a material system are not ordinary numbers, but are rather actions having the property that the order in which they act matters!

This "solution" may sound absurd or insane. But mathematicians had already discovered that logically consistent generalizations of ordinary mathematics exist in which numbers are replaced by "actions" having the property that the order in which one lets them act matters. The ordinary numbers that we use for everyday things like buying a loaf of bread or paying taxes are just a very special case from among a broad set of rationally coherent mathematical possibilities. In this simplest case, A times B happens to be the same as B times A. But here is no logical reason why Nature should not exploit one of the more general cases: there is no compelling reason why our physical theories must be based exclusively on ordinary numbers rather than on actions. Heisenberg's theory, Quantum Mechanics, exploits the more general logical possibility.

Now all this may sound like a lot of mathematical tomfoolery, but the important point is that it leads to a revision of the scientific conception of the nature of reality, and of human beings, that is so profound that it can impact upon the lives of ordinary people.

An example of the change introduced by Heisenberg may be helpful.

In classical physics the center-point of each physical object has, at each instant of time, a well defined location, which can be specified by giving its three coordinates (x, y, z) relative to some coordinate system. For example, the location of a spider dangling in a room can be specified by letting z be its distance from the floor, and letting x and y be its distances from two intersecting walls. Similarly, the velocity of that dangling spider, as she drops to the floor, blown by a gust of wind, can be specified by giving the rates of change of these three coordinates (x, y, z). If each of these three rates of change, which together specify the velocity, are multiplied by the weight (=mass) of the spider, then one gets three numbers, say (p, q, r), that define the "momentum" of the spider. So in classical physics you might use the set of three numbers denoted by (x,y,z) to represent the position of the center point of an object, and the set of three numbers called (p,q,r) to represent the momentum of that object. These are just ordinary numbers that obey the commutative property of multiplication that we all, hopefully, learned in 3^{rd} grade: x*p equals p*x, where * means multiply.

Heisenberg's analysis showed that in order to make the formulas of classical physics describe quantum phenomena, x*p must be different from p*x. Moreover, he found that the difference between these two products must be Planck's constant. [Actually, the difference is Planck's constant multiplied by the imaginary unit i, which is a number such that i times i is minus one.] Thus modern quantum theory was born by recognizing, or declaring, that the symbols used in classical physical theory to represent ordinary numbers actually represent actions such that their ordering in a sequence of actions is important. The procedure of creating the mathematical structure of quantum mechanics from classical physics by replacing numbers by corresponding actions is called "quantization."

This idea of replacing the numbers that specify where a particle is, and how fast it is moving, by mathematical quantities that violate the simple laws of arithmetic may strike you---if this is the first you've heard about it---as a giant step in the wrong direction. You might mutter that scientists should try to make things simpler, rather than abandoning one of the things we really know for sure, namely that the order in which one multiplies factors does not matter. But against that intuition you should bear in mind that this change works beautifully in practice: all of the tested predictions of Quantum Theory are borne out, and these include predictions that are correct to the incredible accuracy of one part in a hundred million. Thus there must be something very very right about quantum theory.

Another example of the conversion of numbers to actions may be helpful here. Consider a bead that can move along a straight wire. The location of the bead along the wire is, according to classical ideas, specified by a single number. Let this number be denoted by the symbol "x". The velocity of the bead along the wire is given by another number, which we will denote by the symbol "v". Another interesting quantity is the "momentum" of the bead. It is the product of the velocity of the bead by the "mass" (weight) of the bead. The momentum is often represented by the symbol "p", and the mass by the symbol "m", so that p equals mv. Also, px equals xp. But Heisenberg discovered that he could compute various observable properties correctly by using certain classical equations, with, however, the symbols x and p in those equations replaced by their quantum counterparts, which are "actions" or "operators" such that the difference between px and xp is proportional to Planck's constant.

The action x is an action that is conceived to be a probing action that is intended to reveal the number x that according to the precepts of classical physics specifies where the (center of the) object of located. The action p is defined analogously. Such actions are highly idealized: they cannot be physically realized. But realistic probing actions exist, and they are the basis of the application of quantum theory to empirical data.

If one were to set Planck's constant equal to zero in Heisenberg's equations one would recover the (physically incorrect) equations of classical physics. Using, on the other hand, the true value of this constant---measured in 1900 by Planck---introduces an element of uncertainty into what our probing actions are able to reveal about the classically conceived properties of physical systems, and entails , in order to tie the theory to human experience in testable ways, the intervention of choices, made by human agents, of which probing action to undertake.
In the context of understanding our own nature the significance of these changes is this. Classical physics reduced human beings to impotent observers of a mechanical universe whose laws were completely described without mentioning either conscious awareness or the seeming capacity of our conscious efforts to influence our bodily actions. That theory has been found to be fundamentally incorrect, and has been replaced by a theory that brings conscious human thoughts into physics in two important ways.

The first way is to alter the mathematical structure of the theory in a way that ties it directly to the acquisition of empirical data. In the final analysis "empirical data" means "experienced data": a scientific theory is required to link statements in the theoretical/mathematical structure to empirical aspects of human experiences. The mathematical structure of a physical theory exists in the minds of the scientists who use the theory to comprehend the structure of their perceptual experiences. The basic interpretational problem is to link together, in a rationally coherent way, these two aspects of human thinking, which I shall call the psychologically described and the mathematically (or physically) described parts of the theory. The mathematically described part might correspond in some way to something that is “really out there”, existing apart from human experience. But the founders of quantum theory recommended that physicists not worry about what is really out there: they should, instead, regard the mathematical structure as a set of rules for computing connections between what physicists do and what they learn. A key part of the training of quantum physicists is to teach them to make this crucial readjustment in their thinking. Insofar as the rules work---i.e., give predictions borne out by experience---the theory gives a “true” idea of relationships that exist within the realm of human thought. Whatever has no impact on connections between human conscious experiences can be regarded as lying outside of science.

This pragmatic stance is a retreat from the “ontological” interpretation of classical physics: i.e., from the idea that the theory describes what actually “exists”, apart from us, as distinct from what we can know. The scope of the new theory is officially restricted to epistemology: to what we can find out, or learn, by initiating appropriate probing actions.

The second way that the new laws bring our consciousness into physics is in association with “free choices” made by causal agents. The new laws permit the occurrence of consciously chosen (probing) actions that can influence physical behavior, yet are not themselves determined by any known law. This revision of the laws of physics severs in one stroke the purely mechanical determinism that has perplexed and hobbled philosophy for three centuries!

Purposeful Actions and Experienced Feedbacks

But how is this huge turnabout achieved?

How can being be replaced by actions, without leaving actions with nothing to act upon?

Quantum theory is built upon the idea of purposeful actions by agents. Each such action is expected or intended to produce an experiential response or feedback. For example, a scientist might act to place a Geiger counter near a radioactive source, and expect to see the counter either “fire” during a certain time interval or not “fire” during that interval. The experienced response, “Yes” or “No”, to the question “Does the counter fire during the specified interval?” specifies one bit of information. Quantum theory is built around such knowledge-acquiring actions of agents, and the knowledge that these agents thereby acquire.

Probing actions of this kind are performed not only by scientists. Every healthy and alert infant is engaged in making willful efforts that produce experiential feedbacks, and he or she soon begins to form expectations about what sorts of feedbacks are likely to follow from some particular kind of effort. Thus both empirical science and normal human life are based on paired realities of this action-response kind, and our physical and psychological theories are both basically attempts to understand these linked realities within a rational conceptual framework.

As another example, consider a single physical object, such as the dangling spider mentioned above, and the set of three numbers x, y, and z that according to the ideas of classical physics specify where the (center of the) object is located. According to quantum theory, no one can ever find out exactly where this center point lies. Accordingly, quantum theory deems superfluous the notion that each object or particle has a well defined location. Thus the new theory can use the symbols x, y, and z that in classical physics represents these three numbers to represent three other things, namely three corresponding actions, x, y, and z. These actions are associated with the acts of acquiring knowledge, and the dynamical laws represent and use only what is knowable in principle.

Although no one can know exactly where the spider is located, a human agent can, by a willful effort, initiate a purposeful action that normally will produce an experiential feedback that can be conceived to provide some information pertaining to the location the spider. For example, one may, by an appropriate willful act, direct one's visual attention to the task of determining whether the spider appears to move during a certain time interval or rather remains stationary. Or one might endeavor to learn whether the spider appears to stay in her web during that interval or not. One bit of information will be supplied by the experienced answer to either one of these yes-or-no queries.

Doing informative experiments depends on someone's being able to distinguish experiences that meet specified criteria from those that do not. Someone must be able to say whether the Geiger counter fired or not, or at least be able to say something about what is going on in the physical world. Science, as we know it, would be difficult to pursue if scientists could make no judgments based on their probing actions, and the resulting experiences, about what was happening in the physical world. Quantum theory thus descends from the airy plane of high-level abstractions, such as the precise trajectories of unseen and unseeable material particles, to the level of more nitty-gritty realities, purposeful actions and experienced feedbacks of specified kinds.

The basic action of an experimental physicist is to set up an experiment and observe the feedback to see whether it conforms or not to some well-posed criterion. An analogous everyday action might be to make the mental effort to raise only one's fourth finger, or to sing a beautiful high C, and then check the feedback to see whether the intention of this purposeful action is realized.

These examples hint at how the quantum framework designed to cover scientific laboratory procedures might be expanded to cover the full range of human endeavors.

A purposeful action by a human agent is partly an intention, described in psychological terms, and partly a physical action, described in physical terms. The feedback also is partly psychological and partly physical. In quantum theory these diverse aspects are all represented by actions in the mathematical structure that emerged from Heisenberg's discovery.

The basic building blocks of quantum theory are, then, a set of purposeful actions by agents, and for each such action an associated possible experiential feedback "Yes", which is a response that the agent can judge to conform to the criterion associated with that purposeful act. A failure of this response to occur is classified as "No." For example, if the agents acts to determine whether the spider stays in its web, then the agent is expecting a feedback that will allow him or her to make the judgment "Yes" the spider stayed in its web or "No" the spider did not stay in its web. More complex inquiries with several alternatives are also possible, but it is enough to consider just the simple "Yes" or "No" cases.

All known physical theories involve idealizations of one kind or another. In quantum theory the main idealization is not that every object is made up of miniature planet-like objects. It is rather that there are agents that perform purposeful acts each of which can result in an experiential feedback that may or may not conform to an experiential criterion associated with that act. One bit of information is introduced into the agent's stream of consciousness, according to whether the feedback conforms or does not conform to that criterion. Thus finding out whether the spider moved or not places the agent on one or the other of two alternative possible distinct branches of the course of world history, at least insofar as effects of that world enter into his stream of consciousness.

John von Neumann, in his seminal book, The Mathematical Foundations of Quantum Mechanics, calls this basic action of making
an inquiry by the name "Process 1", and I shall adopt that terminology A Process 1 action is the mathematical representation of an action consciously chosen by some agent to perform a certain physical inquiry.

Each Process 1 action acts upon a physical state and transforms it. But how does one mathematically represent this physical state and the pertinent transformations of it?

Quantum State of a Physical System

It has already been emphasized that the numbers that describe the state of a physical system in classical physics are replaced by "actions" in the quantum approach, and that the subject matter of the theory is shifted from autonomous self-induced changes in a postulated material structure, to the knowledge acquired by agents as consequences of the empirical/experienced feedbacks they receive from the probing actions they initiate.

But how is this achieved?

In Heisenberg quantum mechanics both the state of a physical system and the probing actions of experimenters are represented by actions of the same kind, which can therefore act upon each other in well defined ways. But how is this done?

One can begin by thinking about a crossword puzzle with N rows and N columns. But instead of putting letters into the little boxes, suppose one puts in numbers. Then one has what is called an N-by-N matrix.

In mathematics the simplest sort of "actions" are represented by N-by-N matrices of this kind. Two N-by-N matrices can be combined by a certain "rule of matrix multiplication" to give a new N-by-N matrix, which can then be combined with another N-by-N matrix, etc, etc.. These rules thus allow combinations of actions to give, according to these well defined rules, new actions. We thereby get a calculus of actions: actions applied to actions give well defined new actions.

Two crossword puzzles cannot normally be combined to give a new crossword puzzle, but once the letters are replaced by numbers, and the rules of combination are specified, the resulting matrices can be combined to give new ones. Then the actions represented by these matrices can be combined in well defined ways.

The state of a physical system is represented in quantum mechanics by an N-by-N matrix, or by a generalization of an N-by-N matrix. The numbers in the matrices give statistical information about the relative probabilities of the two alternative possible answers, "Yes" and "No" to each of the alternative possible probing actions that it is possible to make. Thus the whole orientation of the physical theory is changed by Heisenberg's replacement of numbers by of actions. It becomes a theory not primarily about the automatic development of a physical system left to itself, but rather about the possible effects of alternative possible probing actions upon the state of a probed physical system.

The effect of such a probing action has a simple form. For any allowed probing action there is a way of reorganizing the numbers in the N-by-N matrix that represents the probed system so that the first n rows in the matrix, and also the first n columns of the matrix, correspond to the answer "Yes", to the posed question, whereas the remaining rows and columns correspond to the answer "No". If this question is physically posed, and nature returns the answer "Yes", then the N-by-N matrix that represents the state prior to the probing action gets replaced by a new N-by-N matrix. This new matrix is obtained by leaving unaltered the numbers in the n-by-n submatrix consisting of numbers that lie in both a “Yes” row and a “Yes” column, but setting to zero every other number in the matrix. That is, the N-by-N matrix that represents the state of the observed system before the probing action occurs is “reduced” to a new N-by-N matrix, which is identical to the original in the n-by-n submatrix, but has zeros in every other place. If nature returns the answer “No”, then it is the submatrix consisting of the numbers in both a “No” row and a “No” column that are retained unaltered, with the remaining numbers being set to zero.

Von Neumann’s Process 1 corresponds to physically posing a probing question, but not answering it. This probing process is undertaken by an agent, and is represented by leaving unchanged both the n-by-n “Yes-Yes” submatrix, and the “No-No” submatrix, but setting to zero the remaining numbers. Von Neumann gives no name to the subsequent empirical appearance of either the “Yes” or the “No* outcome. I shall refer to this subsequent appearance of a definite outcome by the name Process 3. Quantum theory gives statistical predictions about this Process 3, but places no specific conditions on which Process 1 action is taken, or when such an action is taken. In von Neumann’s formulation the physical system being probed is, in the final analysis, either the body of the agent or some macroscopic (i.e., large) portion of that body. These direct actions on the body/brain have eventual ramifications on all physical systems that either have had, or will have, physical interactions with that body/brain.

One sees here a huge change of orientation. The aim of the new physics is not to give a description of an objective physical world evolving on its own, which will later, in some yet-to-be-described way, cause us to have experiences. It is rather to express within the mathematical description of the probed system, the physical correlates both of our consciously directed probing actions and of their perceptual feedbacks. The theory is thereby converted from an essentially physical theory of an automatically evolving materialistic universe to an essentially psychophysical theory of mind-body interaction.

Once one gets an answer “Yes” or “No”, then one has a new state of the system just probed, and one can probe it again, and be able to make new statistical predictions, etc., etc.. The corresponding transformations of the state of the physical system being probed stay in step with, and represent in some sense, the evolving state of the observer’s knowledge about the world.

This description of the way quantum theory actually works in practice may help to make the pronouncements of the founders cited above a little less mysterious than they may have originally seemed.

This description of the quantum approach reveals both close mathematical connections, but also enormous conceptual differences, between classical physics and quantum physics. In classical physics the elemental ingredients are tiny invisible bits of matter that are idealized miniaturized versions of the planets that we see in the heavens, and that move in ways unaffected by our scrutiny, whereas in quantum physics the elemental ingredients are purposeful probing actions by agents, the feedbacks arising from these actions, and the not-completely-determined effects of such actions on the physical states that are being probed. These states embody the information about which probing actions have been performed, and what knowledge has been gleaned from these actions.

The physical states defined in this way yield useful statistical predictions about the likely outcomes of the various alternative possible future probing actions. Quantum theory is thus pragmatic in the sense that it is directly about useful and testable theoretically proposed connections between perceptual aspects of human experience, rather than a theory about the imagined motions of fictional atomic-sized planets whose trajectories, even if they did exist, would be in principle unknowable because the probing actions needed to find out what these trajectories are are non-existent in principle.

Given the specific nature of these differences, involving an essential shift from imaginary unknowable entities (possessing assumed properties that render them incompatible with the empirical facts) to empirically validated mathematically expressed relationships between consciously chosen physical probing actions and experienced feedbacks, it becomes plausible that quantum physics might provide a science-based conceptual structure that is better able than classical physics to explain the relationship between the physically and psychologically described aspects of human beings.

Free Choices

Orthodox quantum theory is formulated in a realistic and practical way. It is structured around the activities of human agents, who are considered able to freely elect to probe nature in any one of many possible ways. Bohr emphasized the freedom of the experimenters in passages such as:

> "The freedom of experimentation, presupposed in classical physics, is of course retained and corresponds to the free choice of experimental arrangement for which the mathematical structure of the quantum mechanical formalism offers the appropriate latitude." (Bohr, 1958, p.73)
>
> “To my mind there is no other alternative than to admit in this field of experience, we are dealing with individual phenomena and that our possibilities of handling the measuring instruments allow us to make a choice between the different complementary types of phenomena that we want to study. (Bohr, 1958, p. 51)

This freedom of action stems from the fact that in the original Copenhagen formulation of quantum theory the human experimenter is considered to stand outside the system to which the quantum laws are applied. Those quantum laws are the only precise laws of nature recognized by that theory. Thus, according to the Copenhagen philosophy, there are no presently known laws that fix uniquely the choices made by the agent/experimenter/observer about how the observed system is to be probed. This choice is, in this very specific sense, a “free choice.”

The Copenhagen formulation of quantum theory involves separating the dynamically unified physical world into two parts, the observed and observing systems, which are described in very different ways: the observed system is described in terms of the mathematical operators mentioned above, whereas the observing system is described essentially in terms of the experiences of the agent.

This procedure based on a bifurcation of the physical world into “observer” and “observee” works beautifully in practice. But this chopping of the unified physical world into two parts that are described in different ways is a source of great dissatisfaction among scientists who seek a rationally and dynamically coherent understanding of what is actually going on.

Von Neumann evaded this unnatural splitting of the physical world by including the entire physical world---including the bodies and brains of the human agents---in the physical reality that is described in terms of the mathematical operators. In this formulation the brain of the agent becomes the probed physical system, and the intentional act of the agent is represented by a Process 1 change in the physical state of his brain.

A crucial point is that von Neumann’s inclusion of the entire physical world does not resolve the two “free choice” issues of which of all the logically possible Process 1 actions the agent will choose, or of when the agent will choose to perform the next Process 1 action. These choices remain undetermined in von Neumann’s “orthodox” quantum theory: no rule or law that determines them is specified.

I shall discuss in subsequent chapters some important effects of the Process 1 actions of mind on brain. But the most essential point of this book has already been made. According to classical mechanics, everything that happens in the physical world is determined by a single bottom-up (i.e. working upward from atomic foundations) local-deterministic physical process, and we ourselves are, consequently, mechanical automata. This does not mean that in classical physics high-level processes can have no effect on low-level processes. Certainly the behaviors of macroscopic entities such as wheels, pistons, and weather patterns have important causal consequences. Hence high-level events, entities, and processes can certainly causally influence the course of low-level events. But in classical physics those top-down processes are simply re-expressions of certain features of the basic bottom-up process, which is itself dynamically complete. In orthodox von Neumann quantum theory, on the other hand, the actions of human agents are governed by two processes. One of them is the bottom-up local deterministic process that arises from Heisenberg's procedure of quantizing the classical laws of motion. This process is called Process 2 by von Neumann. Like its classical counterpart, Process 2 is controlled by deterministic laws that are, moreover, local, in the sense that everything is determined by interactions between elements that are localized at space-time points (or in very tiny regions) and that are influenced only by their immediate neighbors.

Process 2 specifies the way the quantum state of a system usually changes (continuously) with the passage of time. But this Process 2 action, by itself, does not yield any predictions concerning relationships between human experiences. Another process, namely Process 1, is needed. At certain instants of time the orderly evolution of the system in accordance with Process 2 is interrupted: a Process 1 action intervenes. According to the pragmatic precepts of quantum theory, this intervention is associated with an inquiry, with a probing action. This Process 1 action is a genuine top-down process, in the sense that it originates in an intentional impulse, and its form reflects that intention. Moreover, this intervention is non local: it acts all at once over a macroscopic region. Furthermore, no currently known law determines which of the many possible Process 1 actions actually occurs: the agent has a "free choice", and this choice, by fixing which probing action is undertaken, has effects on the brain of that agent. Thus quantum theory, unlike classical physics, is intrinsically equipped to yield top-down macroscopic effects of conscious choices upon the mathematically described quantum states of physical systems.

Cloudlike Forms

The quantum state of a physical system is specified, as already mentioned, by a "matrix". However, the quantum state can be described also in terms of cloudlike forms each of which specifies a smeared out region of possible locations of the center point, with a numerical value (associated with probability) assigned to each such location. These cloudlike structures are often called "wave packets."

Simple Harmonic Oscillators

One of the most important and illuminating examples of this cloudlike structure is the one corresponding to a pendulum, or more precisely, to what is called a "simple harmonic oscillator." Such a system is one in which there is a restoring force that tends to push the center of the object to a single "base point" of lowest energy, and in which the strength of this restoring force is directly proportional to the distance of the center point of the object from this base point.

According to classical physics any such system has a state of lowest energy. In this state the center point of the object lies motionless at the base point. In quantum theory this system again has a state of lowest energy. But it is not localized at the base point. It is a cloudlike spatial structure that is spread out over a region that extends to infinity. However, the probability distribution represented by this cloudlike form has the shape of a bell: it is largest at the base point, and falls off in a prescribed manner as the distance of the center point from the base point increases.

If one were to squeeze this state of lowest energy into a more narrow space, and then let it loose, the cloudlike form would explode outward, but then settle into an oscillating motion. Thus the cloudlike spatial structure behaves rather like a swarm of bees, such that the more they are squeezed in space the faster they move relative to their neighbors, and the faster the squeezed cloud will explode outward if the squeezing constraint is released. This property plays a key role in quantum brain dynamics, as we shall soon see

The double-slit experiment

An important difference between the behavior of the quantum cloudlike form and the somewhat analogous classical probability distribution is exhibited by the famous double-slit experiment. If one shoots an electron, an ion, or any other quantum counterpart of a tiny classical object, at a narrow slit then if the object passes through the slit the associated cloudlike form will fan out over a wide angle. But if one opens two closely neighboring narrow slits, then what passes through the slits is described by a probability distribution that is not just the sum of the two separate fanlike structures that would be present if each slit were opened separately. Instead, at some points the probability value will be twice the sum of the values associated with the two individual slits, and in other places the probability value drops nearly to zero, even though both individual fanlike structures give a large probability value at that place. These features of the quantum cloudlike structure make that structure very different from a classical-physics probability distribution, because in the classical case the probabilities arising from the two slits simply add.

The problem here is that this probability structure, which could pertain to a quantum particle such as an electron or a calcium ion, persists even when the particles come one at a time. According to classical physics the individual tiny object must pass through either one slit or the other, so the probability distribution should be just the sum of the contributions from the two separate slits. But it is not. Quantum theory deals consistently with this and all the other non-classical properties of these cloudlike structures.

4. NERVE TERMINALS AND THE NEED TO USE QUANTUM THEORY.

Some neuroscientists who study the relationship of consciousness to brain process want to believe that classical physics will be adequate for that task. That belief would have been reasonable during the nineteenth century, but now, in the twenty-first, it is rationally untenable.

The belief that classical physics should be adequate would have been rational at the end of the nineteenth century because at that time classical physics was believed to be true: the classical laws were believed to govern the behavior of all physical systems, including human brains. The causal structure of nature was asserted to reside in a physical structure specified by local (i.e., contact) conditions on numbers assigned to points in space-time. Of course, ever more complex layers of physical behavior, described in ever more complex languages, could emerge in physical systems of increasing complexity. But all of that complex structure is, according to the classical precepts, completely fixed by a collection of numbers assigned to space-time points, and evolving in accordance with mathematical rules that determine the way that each of these numbers changes in time in terms of other numbers in its immediate neighborhood. Within this local mechanical classical conceptual framework, consciousness, to the extent that it plays any dynamical or causal role in the physical world, is effectively a complex physical property of tiny physical elements, whose changing properties are completely fixed by local mechanical/mathematical laws.
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Now, however, in the twenty-first century, that classical conception of nature is known to be fundamentally incorrect. Many observed macroscopic phenomena are absolutely incompatible with the basic precepts of classical physics. According to the new physical principles, as developed by John von Neumann, the dynamics of a brain is controlled in part by a local deterministic process, Process 2 that is the quantum generalization of the mechanical process of classical physics. But the evolution of physical systems specified by Process 2 is, according to orthodox von Neumann quantum theory, interrupted from time to time by a Process 1 event that (1) is not a local process, (2) is not specified by any currently known local rules, and (3) allows conscious choices to affect brain/body activity. Any rational claim that the conceptual structure of classical physics is, in spite of these huge and seemingly pertinent differences with orthodox contemporary physics, an adequate foundation for an understanding of the relationship between the psychologically and physically described aspects of the mind-brain system must justify itself within the new-physics framework that has replaced the falsified concepts of classical physics. Anyone espousing such an a priori implausible claim---that classical physics suffices---must explain, from within the newer framework, why these huge seemingly pertinent differences between classical and quantum physics do not matter.

To assess the importance of quantum effects in brains within standard (i.e., Copenhagen or von Neumann) quantum theory one must use the von Neumann formulation, because Copenhagen quantum theory is formulated in a way that leaves out the quantum dynamics of the human observer's body and brain. But von Neumann quantum theory makes the brain of the agent the part of the physical system S upon which the crucial Process 1 acts. This Process 1 specifies, in von Neumann quantum theory, the influence of a person's stream of consciousness on the activity in his brain. That influence acts within the clouds specified by quantum theory. However, those clouds (of uncertainty) shrink to points in the classical limit. This shrinkage of these clouds to points completely eliminates the possibility for any effect of an agent's conscious choices upon his physical brain. Thus ignoring quantum effects in the study of the mind-brain connection means, within orthodox von Neumann quantum theory, completely excluding the causal effects, explicitly specified by the theory, of the mind of the agent upon the activities of his brain.

This consideration shows why, in principle, quantum effects cannot be ignored in the study of brain dynamics. But this leads to the further question: How important, quantitatively, are these quantum effects?

These quantum effects can, in principle, be extremely important! This is made particularly evident by an examination of the dynamics of nerve terminals.

Nerve Terminals

Nerve terminals lie at the junctions between two nerves, and mediate the functional connection between them. The way they work is this. Each "firing" of a nerve sends an electrical signal along that fiber. When this signal reaches the nerve terminal it opens up tiny channels in the terminal membrane, through which calcium ions flow into the interior of the terminal. Within the terminal are "vesicles", which are small storage areas containing chemicals called neurotransmitters. The calcium ions migrate from their entry channels to special sites, where they trigger the release of the contents of a vesicle into a gap between the terminal and a neighboring nerve. The released chemicals influence the tendency of the neighboring nerve to fire. Thus the nerve terminals, as connecting links between nerves, are basic elements in brain dynamics.

The channels through which the calcium ions enter the nerve terminal are called "ion channels." At their narrowest points they are not much larger than the calcium ions themselves. This extreme smallness of the opening in the ion channels has profound quantum mechanical import. The consequence is essentially the same as the consequence of the squeezing of the state of the simple harmonic oscillator, or of the narrowness of the slits in the double-slit experiments. The narrowness of the channel restricts the lateral spatial dimension. Consequently, the lateral velocity is forced by the quantum uncertainty principle to become large. This causes the cloud associated with the calcium ion to fan out over an increasing area as it moves away from the tiny channel to the target region where the ion will be absorbed as a whole on some small triggering site, or will not be absorbed at all on that site.

This spreading of the ion wave packet means that the ion may or may not be absorbed on the small triggering site. Accordingly, the vesicle may or may not release its contents. Consequently, the quantum state of the vesicle becomes a mixture consisting of a state where the neurotransmitter is released and a state where the neurotransmitter is not released. This quantum splitting occurs at every one of the trillions of nerve terminals. This quantum uncertainty in what is happening at the level of the nerve terminals propagates via the essentially mechanical Process 2 first to neuronal behavior, and then to the behavior of the whole brain, so that, according to quantum theory, the state of the brain becomes a cloudlike collection of an infinitude of classically describable possible brains, each representing a tendency for some corresponding experience to occur.

What is the effect of this replacement of the single, unique, classically described brain of classical physics by a cloud-like quantum brain state composed, essentially, of myriads of alternative possible classically describable brain states?

A principal function of the brain is to receive clues from the environment, form an appropriate plan of action, and direct the activities of the brain and body specified by the selected plan of action. The exact details of the chosen plan will, for a classical model, obviously depend upon the exact values of many noisy and uncontrolled variables. In cases close to a bifurcation point the dynamical effects of noise might even tip the balance between two very different responses to the given clues: e.g., tip the balance between the 'fight' or 'flight' response to some shadowy form.

The effect of the simultaneous presence, in the quantum state of the brain, of both the "release" and "don't release" options for each vesicle, coupled with the uncertainty in the timing of the vesicle release at each of the trillions of nerve terminals will be to cause the quantum mechanical state of the brain to become a smeared out collection of different macro-states representing different alternative possible plans of action. Thus the effect of quantum theory is to convert the single unique plan of action that a classical model would be expected to generate into cloudlike representation of the brain of the agent that encompasses a whole continuous smear of possible actions. As long as the brain dynamics is controlled wholly by Process 2---which is the quantum analog of motion governed by the Newtonian laws of motion of classical physics---all of the various alternative possible plans of action will exist in parallel, with no one plan of action singled out as the one that will actually occur. Some other process, beyond the local deterministic Process 2, is required to link the cloud of alterative conflicting possibilities to our streams of conscious thoughts. That other process is Process 1. It is a nonlocal process that picks out one probing action from a host of possibilities.

The inadequacy of classical mechanics in the treatment of brain dynamics stems, then, from the quantum uncertainties in the location of the individual calcium ions in nerve terminals---along with a host of other microscopic quantum uncertainties in the brain that we do not need to explicitly describe. These uncertainties at the micro-level would propagate, via Process 2 alone, to uncertainties in the macroscopic state of the brain. The brain becomes, if nothing else intervenes, essentially a smeared out collection of evolving classical possibilities. Process 1 is needed to connect this continuum of macroscopic possibilities to human experience. It is needed in order to allow the probability formulas to work. Without a Process-1 intervention the theory lacks predictive power.

5. TEMPLATES FOR ACTION.

Physical systems can be described in many alterative possible ways. The variables that describe the individual particles of a large system can be combined in ways that produce new variables that are more suited to the description of the observed features of the large system.

When I considered earlier the question of whether quantum effects are important in principle in brain dynamics I focused on the individual calcium ions entering nerve terminals. But Process 1 is associated with conscious experiences, and hence (I shall assume) with variables that describe the collective features of many particles of the brain.

The part of the brain state that corresponds to the intention to produce some specified experiential feedback is expected (by me at least) to be a highly organized large-scale pattern of brain activity that tends to endure for a period of perhaps tens or hundreds of milli-seconds. It must endure for an extended period in order for it to be able to direct the course of brain activities in a way concomitant with the intention. Thus the neural (or brain) correlate of the intentional act should be something like a collection of the vibratory modes of a drumhead in which many particles move in a coordinated way for an extended period of time.

In quantum theory the enduring states are oscillatory states. They are like the lowest-energy state of the simple harmonic oscillator discussed above, which tends to endure for a long time, or like the states obtained from such lowest-energy states by spatial displacements and shifts in velocity. Such states tend to endure as oscillating states, rather than quickly dissolving into chaotic disorder.

I shall call by the name Template for Action a macroscopic oscillatory brain state that will, if held in place for an extended period, tend to produce some particular action. The "Yes" feedback associated with a Process 1 action is assumed to be a Template for Action. Then each purposeful Process 1 action is associated with an associated pattern of brain activity. This pattern is the one that will be actualized by the "Yes" answer to the probing action specified by that purposeful action. This pattern will, if held in place for an extended period, tend to bring the intended action into being.

Process 1 thus picks out one template for action from the continuous smear of templates of action generated by Process 2.

This understanding of the nature and role of Process 1 arises in a natural way from von Neumann's formulation of quantum theory. It ties psychologically described intentions to their brain correlates via a key dynamical element of the theory, von Neumann's Process 1. But a key question then arises: How does this dynamical psycho-neurological connection via Process 1, which merely poses a question, allow a person's conscious choices to exercise effective control over his or her physical actions?

6. THE QUANTUM ZENO EFFECT.

An important feature of the dynamical rules of quantum theory is this: Suppose a Process 1 event that leads to a "Yes" outcome is followed by a rapid sequence of very similar Process 1 events. That is, suppose a sequence of very similar intentional acts is performed, and that the events in this sequence occur in very rapid succession on the time scale of the evolution of the "Yes" state. Then the dynamical rules of quantum theory entail that the sequence of outcomes will, with high probability, all be "Yes": the "Yes" state will, with high probability, be held approximately in place by the rapid succession of intentional acts, even in the face of very strong forces that would, in the absence of this sequence of intentional acts, quickly cause the state to become very different from "Yes". By virtue of the quantum laws of motion a strong intention, manifested by the high rapidity of the similar intentional acts, will tend to hold in place the associated template for action.

The timings of the Process 1 actions are, within the orthodox formulations, controlled by the "free choices" on the part of the agent. If we add to the von Neumann rules the assumption that the rapidity of these similar Process 1 can be increased by mental effort then we obtain, as a rigorous mathematical consequence of the basic dynamical laws of quantum mechanics described by von Neumann, a potentially powerful effect of mental effort on brain activity!

This “holding-in-place” effect is called the Quantum Zeno Effect. This appellation was used by the physicists E.C.G. Sudarshan and R. Misra, to emphasize a rough similarity of this effect to a paradox discussed by the fifth century B.C. Greek philosopher, Zeno the Eleatic. This “holding” effect is a clear and unambiguous consequence of the basic quantum laws. In the context of the interaction between mental effort and bodily function, the physical system being probed or acted upon by consciousness is the macroscopic enduring oscillatory patterns of brain/body activity identified as a “Template for Action”. The probing actions must occur rapidly on the scale of these macroscopic oscillations in order for the quantum Zeno effect to come into play, and hold this Template of Action in place.

The “Quantum Zeno Effect” can, in principle, hold a purposeful intention in place in the face of strong mechanical forces that would tend to disrupt it. This means that agents whose efforts can influence the rapidity of Process 1 actions would enjoy a survival advantage over competitors that lack such features, for they could sustain beneficial templates for action in place longer than competitors who lack this capability. This means that the dynamical rules of quantum mechanics can, in principle, give conscious effort the causal efficacy needed to permit its evolution and development via natural selection.

7. THE EFFECTIVENESS OF WILL.

A person’s experiential life is a stream of conscious experiences. The person’s experienced ‘self’ is part of this stream of consciousness: it is not an extra thing that is outside or apart from the stream. In James’s words “thought is itself the thinker, and psychology need not look beyond.” The “experienced self” is a slowly changing “fringe” part of the stream of consciousness. It provides a background for the central focus of attention.

The physical brain, evolving mechanically in accordance with the local deterministic Process 2, does most of the necessary work of the brain, without the intervention of Process 1. It does its job of creating, on the basis of its interpretation of the clues provided by the senses, a suitable response. But, due to the way it operates. Process 2 necessarily generates, in a continuously evolving way, an amorphous mass of overlapping and conflicting templates for action. A Process 1 action, if it occurs, extracts from this jumbled mass of possibilities a particular pair of alternative possibilities, one labeled “Yes” the other labeled “No”. In order to tie this Process 1 intervention to the idea of physically posing a query with an intended recognizable feedback “Yes”, the physical state of the brain/body corresponding to “Yes” is assumed to be a template for action: an enduring configuration in which all of the modular components of the brain act together in a mutually supportive configuration of non-discordant harmony that tends to prolongs itself into the future and produce a particular feedback. The ultimate reason that the rules for Process 1 interventions take this particular form is perhaps a law of survival of the fittest, but the present motivation is merely to fill in some dynamical details that are left open in von Neumann quantum theory in a way concordant with the way that theory works at the practical level.

The quantum rules do not assert that, once a Process 1 intervention occurs, this “Yes” part of the prior state S necessarily comes into being: they assert, instead, that once a Process 1 intervention occurs, then this “Yes” component will come into being with a specified probability, and that if the “Yes” state does not come into being then the alternative possibility “No” will come into being.

If we now augment von Neumann’s theory by the assumption that the rate at which these Process 1 interventions occur can be increased by mental effort, then the phenomena of “will” can be dynamically understood: effortful control of the rate of the Process 1 actions can, by means of the quantum Zeno effect, hold a template of action in place, overriding strong mechanical forces arising from Process 2, and cause a large deviation of brain activity from what it would be if no mental effort were made.

Does this quantum-physics-based conception of the dynamical connection between mind and brain explain anything?

This theory was already in place when a colleague, Dr. Jeffrey Schwartz, brought to my attention some passages from ``Psychology: The Briefer Course'', written by William James. In the final section of the chapter on Attention James (1892) writes:

``I have spoken as if our attention were wholly determined by neural conditions. I believe that the array of things we can attend to is so determined. No object can catch our attention except by the neural machinery. But the amount of the attention which an object receives after it has caught our attention is another question. It often takes effort to keep mind upon it. We feel that we can make more or less of the effort as we choose. If this feeling be not deceptive, if our effort be a spiritual force, and an indeterminate one, then of course it contributes coequally with the cerebral conditions to the result. Though it introduce no new idea, it will deepen and prolong the stay in consciousness of innumerable ideas which else would fade more quickly away. The delay thus gained might not be more than a second in duration---but that second may be critical; for in the rising and falling considerations in the mind, where two associated systems of them are nearly in equilibrium it is often a matter of but a second more or less of attention at the outset, whether one system shall gain force to occupy the field and develop itself and exclude the other, or be excluded itself by the other. When developed it may make us act, and that act may seal our doom. When we come to the chapter on the Will we shall see that the whole drama of the voluntary life hinges on the attention, slightly more or slightly less, which rival motor ideas may receive. ..."

In the chapter on Will, in the section entitled “Volitional effort is effort of attention” James writes:

“Thus we find that we reach the heart of our inquiry into volition when we ask by what process is it that the thought of any given action comes to prevail stably in the mind.”

and later

“The essential achievement of the will, in short, when it is most `voluntary,' is to attend to a difficult object and hold it fast
before the mind. ... Effort of attention is thus the essential phenomenon of will.”

Still later, James says:

“Consent to the idea's undivided presence, this is effort's sole achievement.”...“Everywhere, then, the function of effort is
the same: to keep affirming and adopting the thought which, if left to itself, would slip away.”

James apparently recognized the incompatibility of these pronouncements with the physics of his day. At the end of “Psychology: The Briefer Course” he said, presciently, of the scientists who would one day illuminate the mind-body problem:

“the best way in which we can facilitate their advent is to understand how great is the darkness in which we grope, and never forget that the natural-science assumptions with which we started are provisional and revisable things.”

It is a testimony to the power of the grip of old ideas on the minds of many scientists and philosophers alike that what was apparently evident to William James already in 1892, namely that a revision of the precepts of nineteenth century physics would be needed to accommodate the structural features of consciousness, still fails to be recognized by many of the affected professionals even today, more than three-quarters of a century after the downfall of classical physics---foreseen by James---has come, much-heralded, to pass.

James’s description of the effect of volition on the course of mind-brain process is remarkably in line with what had been proposed, independently, from purely theoretical considerations of the quantum physics of this process. The connections specified by James are explained on the basis of the same dynamical principles that had been introduced by physicists to explain atomic phenomena. Thus the whole range of science, from atomic physics to mind-brain dynamics, is brought together in a single rationally coherent theory of an evolving cosmos that is constituted not of matter as classically conceived, but of a sequence of actual events, and an evolving mathematically specified (quantum) state of the universe. Each such event has both mental and physical aspects, and the mathematically specified state is regarded as, and behaves like, a state of knowledge. Hence the materialist conception of nature postulated by physicists of the seventeenth century has given way to a rationally coherent and pragmatically successful psychophysical conception.

No comparable success has been achieved within the framework of classical physics, in spite of intensive efforts that have spanned more than three centuries. No rational description of what consciousness does and how it does it has been achieved within the framework provided by classical physics. The reasons for this failure are easy to see: classical physics systematically exorcizes all traces of mind from its precepts, and thereby banishes any logical foothold for recovering mind. Moreover, according to the empirically supported quantum physics, all causal effects of consciousness act within the latitude provided by the uncertainty principle, and this latitude shrinks to zero in the classical approximation. Hence the dynamical role of consciousness and willful effort is squeezed to nothing in the classical approximation.

A great deal has happened in psychology since the time of William James. Much of the data pertaining to the question of the effects of effort has been assembled in Harold Pashler's book The Psychology of Attention. I argue in Appendix A that these data give significant support to the quantum theory of the mind-brain connection advanced here. Appendix B cites empirical support from neuroscience.

8. APPLICATION TO NEUROPSYCHOLOGY

In the orthodox pragmatic quantum approach we take as primary input variables our choices of how we shall act, instead of postulated variables that are supposed to fix how we act. From the perspective of practical utility the quantum approach is optimal: the theory claims to provides rules that allow us to combine what we know with what we can choose to do, in order to compute as much as it is possible to know about what is likely to happen to us in each of the alternative possible conditions that we might choose to create by our action, without any consideration of things that we can never know. The approach deals exclusively with knowables, rather than beables: with what can be known, not with what can be.

Quantum theory injects directly into the causal structure the phenomenal descriptions that we human beings use in order to communicate to our colleagues how we have acted and what we have learned. By introducing these descriptions into the theoretical structure it is able to achieve a useful and testable causal structure, while rejecting the classical idea that causation is entirely "bottom up"--- i.e., is expressible in terms of local mechanical interactions between tiny mindless entities. The Heisenberg Uncertainty Principle renders the application of that ideal unachievable in principle. The inapplicability of "bottom up" determinism opens the door to the practical quantum alternative of replacing atomic-level unknowables by our knowable and empirically controllable actions.

Quantum physics works, in practice, better in neuropsychology than its classical approximation precisely because it inserts knowable choices made by human agents into the dynamics in place of unknowable-in-principle microscopic variables. To illustrate this point we apply the quantum approach to the experiment of Ochsner et al. (2002).

Reduced to its essence this experiment consists first of a training phase in which the subject is taught how to distinguish, and respond differently to, two alternative possible instructions, given while viewing emotionally disturbing visual images. One instruction "attend" means "passively be aware of, but not try to alter, any feelings elicited by the stimulus", whereas "reappraise" means "actively reinterpret the content so that it no longer elicits a negative response". The subjects then perform these mental actions during brain imaging. The visual stimuli when passively attended to activate limbic brain areas and when actively reappraised activate prefrontal cerebral regions.

From the classical materialist point of view this is essentially a conditioning experiment, where, however, the "conditioning" is achieved via linguistic communications pertaining to cognitive concepts. But how do the cognitive realities involved in "knowing", "understanding", and "feeling" arise out of motions of the miniature planet-like objects of classical physics, which have no trace of any experiential quality? And how do the vibrations in the air that carry the instructions get converted into feelings of understanding? And how do these feelings of understanding get converted to conscious effort, the presence or absence of which determine whether the limbic or frontal regions of the brain will be activated?

Within the framework of classical physics these connections between feelings and brain activities need in principle to be answered: the theory must be deemed incomplete until the answers are supplied.

The materialist claim is that someday these connections will be understood. Karl Popper called this historicist prophecy "promissory materialism". But the question is whether these connections should reasonably be expected to be understood in terms of a physical theory that is known to be false, and is, moreover, false by virtue of the fact that it enforces an approximation that eliminates a causal connection between the psychologically and physically described aspects of nature that the more accurate theory describes. To expect the mind-brain connection to be ultimately understandable within such an approximation is scientifically unreasonable.

There are important similarities and also important differences between the classical and quantum explanations of the experiments of Ochsner et al. (2002). In both approaches the atomic constituents of the brain can be conceived to be collected into nerves and other biological structures, and into fluxes of ions and electrons, which can all be described reasonably well in essentially classical terms. But in the classical approach the dynamics must in principle be describable in terms of the local deterministic classical laws that, according to the classical principles, are supposed to govern the motions of the atomic-sized entities, and thence all physical systems built out of them.

The orthodox quantum approach is essentially different. The quantum laws are organized around events that increase the amount of information lodged in the psychologically described component of the theoretical structure. The correlates of these psychologically described events in the quantum state of the associated brain are specified by a sequence of Process 1 events, each followed by a Process 3 choice of which of the discrete options specified by Process 1 actually occurs. When no effort is applied, the temporal development of the body/brain will be roughly in accord with the principles of classical statistical mechanics, for reasons to be described in the next section. But important departures from the classical statistical predictions can be produced by conscious effort. This effort can cause to be held in place for an extended period a pattern of neural activity that constitutes a template for action. This holding-in-place action can tend to cause the action specified by that template to occur.

In the quantum treatment of the Ochsner experiments the effort of the subject to “reappraise” causes the “reappraise” template to be held in place, and the holding in place of this template causes the suppression of the limbic response. These causal effects are, via the quantum Zeno effect, direct mathematical consequences of the quantum rules. Thus the “subjective” and “objective” aspects of the data are tied together by quantum rules that directly specify the causal effects upon the subject’s brain of the choices made by the subject, without needing to specify how these choices came about. The form of the quantum laws thus accommodates a natural dynamical breakpoint between the cause of willful action, which is not specified by the theory in its present pragmatic form, and its effects, which are specified by the theory. Thus the conscious choices can consistently be treated as empirically specified input variables, in accordance with the actual experimental situation, just as they are in the realm of atomic physics. See Schwartz (2004) for more details.

9. RECENT VIEWS IN NEUROSCIENCE AND PHILOSOPHY.

A tremendous burgeoning of interest in the problem of consciousness is now in progress. The grip of the behaviorists who sought to banish consciousness from science has finally been broken. This shift was ratified, for example, by the appearance of a special issue of Scientific American entitled The Hidden Mind. (August 2002).

The lead article, written by Antonio Damasio, begins with the assertion: "At the start of the new millennium, it is apparent that one question towers above all others in the life sciences: How does the set of processes we call mind emerge from the activity of the organ we call brain?" He notes that some thinkers "believe the question to be unanswerable in principle'' while "For others, the relentless and exponential increase in knowledge may give rise to the vertiginous feeling that no problem can resist the assault of science if only the science is right and the techniques are powerful enough." (My emphasis) He notes that "The naysayers argue that exhaustive compilation of all these data (of neuroscience) adds up to correlates of mental states but to nothing resembling an actual mental state." (His emphasis) He adds that: "In fact, the explanation of the physics related to biological events is still incomplete" and states that "the finest level of description of mind … might require explanation at the quantum level." Damasio makes his own position clear: "I contend that the biological processes now presumed to correspond to mind in fact are mind processes and will be seen to be so when understood in sufficient detail."

With "biological processes" understood to be quantum processes, including the key Process 1, I would agree that those biological processes are mind processes.

The possibility that quantum physics might be relevant to the connection between conscious process and brain process was raised also by Dave Chalmers, in his contribution "The Puzzle of Conscious Experience" to The Hidden Mind. However, he effectively tied that possibility to a proposal put forth by Roger Penrose (1989, 1994) and, faulting that particular approach, rejected the general idea.

The deficiency of Penrose's approach identified by Chalmers is that it fails to bring in consciousness: it is about certain brain processes that may be related to consciousness, but "…the theory is silent about how these processes might give rise to conscious experience. Indeed, the same problem arises with any theory of consciousness based only on physical processing."

Penrose's treatment does indeed focus on physical processing. But quantum theory itself is intrinsically psychophysical: it is a theory about the structure of human experience that is erected upon a mathematical generalization of the laws of classical physics.

Chalmers goes on to expound upon the “explanatory gap” between, on the one hand, theoretical understanding of the behavioral and functional aspects of brain processes and, on the other hand, an explanation of how and why the performance of those functions should be accompanied by conscious experience. Such a gap arises in the classical approximation, but not in orthodox quantum theory, which is fundamentally a weaving of psychologically described realities into the framework of mathematical physics.

The conflating of Nature herself with the impoverished mechanical conception of it adopted by scientists during the seventeenth century has derailed the philosophies of science and of mind for more than three centuries, by presenting them with an irresolvable dilemma: the presence of our physically efficacious thoughts in a world built of tiny mindless mechanical bits completely controlled by local deterministic mechanical laws.

This now-falsified classical conception of the world still exerts a blinding effect. For example, Daniel Dennett (1994: 237) says that his own thinking rested on the idea that “a brain was always going to do what it was caused to do by current, local, mechanical circumstances.” But by making that judgment he tied his thinking to the physical half of Cartesian dualism, or its child, classical physics, and thus was forced in his book “Consciousness Explained” (Dennett, 1991) to leave consciousness out, as he himself admits, but tries to justify, at the end of the book. By accepting the classical approximation, which squeezes the effects of consciousness out of the dynamics, Dennett cuts himself off from any possibility of validly explaining the physical efficacy of our conscious efforts.

Francis Crick and Christ of Koch begin their essay in The Hidden Mind entitled “The Problem of Consciousness” with the assertion: “The overwhelming question in neurobiology today is the relationship between the mind and the brain.” But after a brief survey of the difficulties in getting an answer they conclude that: “Radically new concepts may indeed be needed---recall the modifications in scientific thinking forced on us by quantum mechanics. The only sensible approach is to press the experimental attack until we are confronted with dilemmas that call for new ways of thinking.”

However, the two cases compared by Crick and Koch are extremely dissimilar. The switch to quantum theory was forced upon us by the fact that we had a very simple system---consisting of a single hydrogen atom interacting with the electromagnetic field---that was so simple that it could be exactly solved by the methods of classical physics, but the calculated answer did not agree with the empirical results. There was initially no conceptual problem. It was rather that precise computations were possible, but gave wrong answers. Here the problem is reversed: precise calculations of the dynamical brain processes associated with conscious experiences are not yet possible, and hence have not revealed any mismatch between theory and experiment. The problem is, rather, a conceptual one: the concepts of classical physics that many neurobiologists are committed to using are logically inadequate because, unlike the concepts of quantum physics, they exclude two key protagonists, our conscious thoughts and efforts.

Dave Chalmers emphasizes this conceptual difficulty, and concludes that experimental work by neurobiologists is not by itself sufficient to resolve “The Puzzle of Conscious Experience”: better concepts are also needed. He suggests that the stuff of the universe might be information, but then, oddly, rejects the replacement of classical physical theory, which is based on material substance, by quantum theory, which is built on the information contained in experienced increments of knowledge.

John Searle is perhaps the strongest contemporary voice calling for a forthright acknowledgement of both the existence of the subjective realities, and also the need to explain them, rather than trying to explain them away. His recent views mesh fairly well with the quantum approach developed here.

In his recent article in the Journal of Consciousness Studies Searle (2000) reiterates his longtime themes:

1. Consciousness is a real biological phenomenon.
2. It consists of inner, qualitative, subjective, unified states of sentience, awareness, thoughts and feelings.
3. This unified field of conscious subjective awareness is not reducible to any third-person phenomena.
4. All of our conscious states are caused by lower-level neuronal processes in the brain.
5. All of our conscious states are themselves features of the brain.

If one were to accept the classical-physics conception of the brain then there would appear to be a conflict between claims 3 and 5. For if a brain were a conglomeration of particles, which, as the objective elements of nature, are third-person entities, and conscious states are features of these conglomerations, as asserted by claim 5, then consciousness seems to be reduced to third-person phenomena, in violation of claim 3. In short, Searle needs to abandon the precepts of classical physics, in order to make his stance rationally tenable!

In quantum theory the brain is not just a conglomeration of particles. It is a mathematically describable representation of increments of knowledge that represents also objective tendencies for future increments of knowledge to occur. Why cling to seventeenth physical precepts that are known to be false, when their twentieth century replacements allow rationality to be restored?

Later on, Searle introduces “psychological processes” by observing that people sometimes give ‘reasons’ for acting as they do. But he notes that these ‘reasons’ are not always conclusive, or sufficient to entail the actions they promote. He wishes to consider the possibility that although the psychological processes may be indeterministic, the underlying “neurobiological process” is deterministic. He then says that combining psychological indeterminism with neurobiological determinism---“is intellectually unsatisfying because it is a modified form of epiphenomenalism. It says that the psychological processes of decision making really do not matter. The entire process is deterministic at the bottom level, and the idea that the top level has an element of freedom is simply a systematic illusion. … The bodily movements would be exactly the same regardless of how these processes occurred.”

Searle continues: “Maybe that is how it will turn out, but if so the hypothesis seems to me to run against everything we know about evolution. It would have the consequence that the incredibly elaborate, complex, sensitive and ---above all---biologically expensive system of human and animal conscious rational decision-making would actually make no difference whatever to the life and survival of the organism. Epiphenomenalism is a possible thesis, but it is absolutely incredible, and if we seriously accept it, it would make a change in our world view, that is, in our conception of our relations to the world, more radical than any previous change, including the Copernican Revolution, Einsteinian relativity theory and quantum theory.”

The sort of epiphenomenal consciousness that Searle finds incredible is what necessarily arises from classical physics, which he therefore ought to reject. Quantum theory breaks that bottom-up local mechanical determinism, and thereby also the epiphenomenalism that Searle finds so absolutely incredible, and allows psychologically described rational reasons that are not fully controlled by bottom up processes to enter via Process 1 into the control of brain behavior. Searle’s arguments are directly supportive of the quantum approach.

10. Penrose-Hameroff and Decoherence.

Important features of the von Neumann approach being described here can be brought out by comparing them to properties of a somewhat similar proposal put forth by Roger Penrose and Stuart Hameroff (1996). Their theory is also based on the von Neumann formulation, but it brings in several added ideas that are not used in the approach employed here.

An essential difference between the present proposal and that of Penrose and Hameroff is that their theory depends on establishing a property called quantum coherence over an extended portion of the brain, whereas the theory being described here does not. This property is a technical matter that I do not want to enter into here, beyond remarking that most quantum physicists deem it highly unlikely that the quantum coherence required by the Penrose-Hameroff theory could be sustained in a warm, wet, living brain. (See (Tegmark, 2000) and (Hagen, 2002))

The (presumed) lack of long-range quantum coherence in a living brain is a great asset to the von Neumann approach described in this book. This lack of long-range quantum coherence means that the quantum “clouds” mentioned above can be conceived to be, to a very good approximation, simply a collection of classically conceived alternative possible states of the brain. These alternative possible classically described brains will all exist together as “parallel” parts of a single reality. However, these quasi-classical brain states are allowed to interact with the almost identical brain states in this collection of “possibilities”. That feature is completely different from classical physics: one classical possibility cannot interact with an alternative classical possibility. However, the only pertinent effect of this non-classical feature, apart from allowing chemical interactions, appears to be the quantum Zeno effect. This allows non-physicists to have an intuitive approximately correct idea of the quantum state of a brain. In terms of the matrices described earlier, this quasi-classical feature corresponds to all of the numbers in the matrix that represents the state of a brain being very small, except those numbers such that their row and column labels are very nearly the same. (See Appendix C for further details.)

A second difference is that the Penrose-Hameroff theory depends on the complex question of quantum gravity, which is currently not under good theoretical control, whereas the present approach is based only on the fundamental principles of quantum theory, which, thanks to the efforts of John von Neumann, are under good control.

The third difference is that Penrose’s approach involves a very much disputed argument that claims to deduce from (1), the fact that mathematicians construct proofs that they believe to be valid, and (2), some deep mathematical results due to Kurt Gödel, the conclusion that conscious thought must involve a non-mechanical process. Quantum theory certainly allows this possibility, because it gives no rules for determining the “free” choices made by the agents. But Penrose uses his Gödel argument to conclude that consciousness cannot be accommodated by classical physics. The present approach argues for roughly the same conclusion from known physical features of the brain, such as the structure of nerve terminals.

The fourth difference is the fact, already emphasized by Chalmers, that Penrose’s theory of consciousness turns out to be about brain, dynamics, but is silent about how brain activity is connected to consciousness, per se. The present work is about precisely this latter question.

On the whole, Penrose's approach is basically similar to the one followed here, because both are based on von Neumann's formulation of quantum theory, and on the fact that orthodox quantum theory involves abrupt interventions of Process 1 actions that are closely connected to consciousness, but are not governed by the local deterministic quantum mechanical process (Process 2) that is the quantum-mechanical generalization of the matter-based dynamical process of classical physics.

11. Non-Orthodox Versions of Quantum Theory and the Need for Process 1.

Some physicists reject the orthodox (Copenhagen/von Neumann) interpretations, and have put forth alternative proposals. The origin of their dissatisfaction is the efficacious interventions of our streams of conscious thoughts into basic physical theory. However, our conscious thoughts are certainly parts of reality, and they are, indeed, the very parts of reality whose existence is least in doubt. Every part of reality ought to have some effect upon the whole. Hence it seems not only natural, but also imperative, that the laws of nature should provide a way for our minds to influence the rest of nature, and, in particular, the flow of events in our brains. Thus the incorporation by quantum theory of mental events into brain dynamics would appear to be a major step in the right direction. Nevertheless, those critics cling to the nineteenth century notion that the physical workings of brains can be completely described without ever considering idea-like realities, which are deemed to be either redundant arrangements of mindless micro-realities, or causally inert bystanders. The two most prominent of these non-orthodox approaches are the Many-Worlds and Pilot-Wave models.

The Many-Worlds (or Many-Minds) Approach

I received recently a query from a colleague, who wrote:

I would appreciate your answering a question I have.

There is much disagreement in the literature about the reduction process and how it works, including controversy over whether there is any such thing as reduction. I have read numerous statements from physicists that measurement involves interaction of a quantum system with its environment, and is (it is asserted) therefore "nothing but" Schroedinger evolution on a larger system.

It is indeed sometimes claimed that the interaction of a system being probed with its environment effectively solves the measurement problem (which is essentially the problem of how to "understand" or "interpret" the mathematical rules of quantum theory). However, the principal investigators of the effects of these interactions (e.g., E. Joos, 1996; D. Zeh, 1996; W. Zurek, 2002) make no such strong claim. Joos (p.3) emphasizes that even when the interaction with the environment is included one is left with not one single classical world but with a host of possible classical worlds “thus leaving the measurement problem essentially unsolved (unless one is willing to accept some variant of the Everett interpretation)”. Zeh (p.17), commenting on the problems that remain after the interaction with the environment has been included, says “A way out of this dilemma in terms of the wave function itself seems to require one of the following two possibilities: (1) a modification of the Schroedinger equation that explicitly describes a collapse… or (2) an Everett type of solution, in which all measurement outcomes are assumed to coexist in one formal superposition, but to be perceived separately as a consequence of their dynamical decoupling.” This “Everett type of solution” is usually called a Many Worlds or a Many Minds solution.

Zurek (p.5) says:

> At first glance, the Many Worlds and Copenhagen Interpretation have little in common. The Copenhagen Interpretation demands an a priori “classical domain” with a border that enforces a classical “embargo” by letting through just one potential outcome. The Many Worlds Interpretation aims to abolish the need for a border altogether. Every potential outcome is accommodated in the ever-proliferating branches of the wave function of the Universe. The similarity between the difficulties faced by these two viewpoints becomes apparent, nevertheless, when we ask the obvious question, “Why do I, the observer, perceive only one of the outcomes?” Quantum theory with its freedom to rotate bases in the Hilbert space, does not even define which states of the Universe correspond to the “branches.” Yet our perception of a reality with alternatives---not a coherent superposition of alternatives---demands an explanation of when, where, and how it is decided what the observer actually records. Considered in this context, the Many Worlds Interpretation in its original version does not really abolish the border but pushes it all the way to the bounbary between the physical Universe and consciousness. Needless to say, this is a very uncomfortable place to do physics.

Later on (p.20-21) he returns to this problem: “why do we perceive just one of the quantum alternatives?” “the process of decoherence we have described above is bound to affect the states of the brain…decohence applies to our own “state of mind.” “There is little doubt that the process of decoherence sketched in this paper is an important element of the big picture… There is even less doubt that this rough outline will be further extended. Much work needs to be done, both on technical issues…and on problems that require new conceptual input (such as … answering the question of how an observer fits into the big picture.)”

These comments make clear the fact that interaction with the environment (and the resulting technical effect known as environmental decoherence) does not by itself solve the measurement problem, namely the problem of accounting for the fact that an observer perceive just one classically describable world, not the infinite collection of them generated by Process 2 acting alone, including all effects of the environment.

The question, then, is whether the Many Worlds/Minds option is rationally acceptable. I have described in (Stapp, 2002) a specific difficulty with the many-worlds approach that is sufficiently serious to block, at the present time, the claim that the Schroedinger equation alone (i.e., Process 2), including all interactions with the environment, is sufficient---without Process 1, or some surrogate of Process 1---to tie the quantum mathematics to testable predictions about human experiences. Such predictions are required for the theory to be scientifically meaningful, and they are obtained in the Copenhagen/von Neumann orthodox approach only by bringing in Process 1 interventions.

The reason, in brief, why Process 1, or something that does the same job, seems to be needed is this: If the universe has been evolving since the big bang solely under the influence of the Schroedinger equation---i.e., Process 2---then every object and every human brain would by now, due to the uncertainty conditions on the original positions and velocities, be represented in quantum theory by an amorphous continuum; the center-point of each object would not lie at a particular point, or even be confined to a small region, but would be continuously spread out over a huge region. Likewise, the state of the brain of every observer of this object would be a smeared out conglomeration of many different classical-type brains. That is, if a human person were observing an object, whose center-point, as specified by its quantum state, were spread out over a region several meters in diameter, then the state of the brain of that person would have, for each of these different locations, a part corresponding to the observer's seeing the object in that location. If each of these parts of the brain were accompanied by the corresponding experience, then there would exist not just one experience corresponding to seeing the object in just one place, but a continuous aggregation of experiences, with one experience for each of the possible locations of the object in the large region. Thus this theory is often called, quite rightly, a "many-minds" interpretation: each person's brain evolves quickly into a smeared out continuum, and each stream of consciousness would be part of a continuous blur of classically describable possibilities.

In order to extract from quantum theory a set of predictions pertaining to human experiences, and hence to give empirical meaning to the theory, this smeared out collection of different brain structures must be resolved in a very special way into a collection of discrete parts, each corresponding to one possible experience. This discreteness condition is a technical point, but it constitutes the essential core of the measurement problem. Hence I must explain it!

Evolution according to the Schroedinger equation (Process 2) generates in general, as I have just explained, a state of the brain of an observer that is a smeared out continuum of component parts. One cannot assign a nonzero probability to each one of such a continuum of possibilities, because the total probability would then be infinity, instead of one (unity). However, the mathematical rules of quantum theory have a well-defined way to deal with this situation: they demand that the space of possibilities be divided in a certain very restrictive way into a countable set of alternative possibilities, where a "countable" set is a set that can be numbered (i.e., placed in one-to-one correspondence with the whole numbers 1, 2, 3, … or with some finite subset of these numbers.) The need to specify a particular countable set of parts is the essential problem in the construction of a satisfactory quantum theory. But then the technical problem that the Many-Worlders must resolve is this: How does one specify a satisfactory particular countable set of different brain states from Process 2 alone, when Process 2 is a continuous local process that generates a structure that continuously connects components that correspond to very different experiences, and hence must belong to different members of the countable set? The problem is to divide a continuum of brain states into a countable set of discrete (and orthogonal) components by means of the continuous Process 2 alone.

Copenhagen quantum theory accomplishes this selection of a preferred set of discrete states by means of an intervention of the experimenter. In the simplest case the countable set of distinguishable experiences has just two elements, "Yes" and "No". The experimenter selects a particular probing action that picks out from the continuously infinite set of possible queries some particular one. In this way, the basic problem of specifying a countable set of discrete parts is solved by bringing into the theory choices on the part of the experimenter. Von Neumann solves this discreteness problem in this same way, and gives this crucial agent-dependent selection process the name "Process 1".

Einstein (1951, p. 670) posed essentially the same problem in a clear way. Suppose a pen that draws a line on a moving scroll is caused to draw a blip when a radio-active decay is detected by some detector. If the only process in nature is Process 2, then the state of the scroll will be a blurred out state in which the blip occurs in a continuum of alternative possible locations. Correspondingly, the brain of a person who is observing the scroll will be in a smeared out state containing a continuously connected collection of components, with one component corresponding to each of the possible locations of the blip on the scroll. But how does this smeared out continuously connected state of the brain get divided by Process 2 alone into components to which well-defined probabilities can be assigned? The quantum statistical predictions cover only those cases in which there is a specified countable collection of distinct possibilities.

A key feature of the orthodox approach is the "empirical fact" that experimenters do have definite thoughts, and that they can therefore place the devices in definite locations. Thus it is the discreteness of the choice made by the experimenter that resolves the discreteness problem. But an experimenter represented by a state governed solely by Process 2 has nothing discrete about him: his brain is a continuous smear with no dynamically defined dividing lines.

The founders of quantum theory (and von Neumann) recognized this basic problem of principle, and in order to resolve it went to a radical and revolutionary extreme: they introduced human experimenters with efficacious free choices into the physical theory. This was a giant break from tradition. But the enormity of the problem demanded drastic measures. Because such powerful thinkers as Wolfgang Pauli and John von Neumann found it necessary to embrace this revolutionary idea, anyone who claims that this unprecedented step was wholly unnecessary certainly needs to carefully explain why. This has not yet been done. (Further details are given in Appendix C)

Although bringing human agents into the dynamics is certainly very contrary to the ideas of classical physics, the notion that our streams of consciousness play some important dynamical role in the determination of our behavior is not outlandish: it is what one would naturally expect. Orthodox quantum theory solves the basis problem in a way that allows our thoughts to affect our actions.

Bohm's Pilot-Wave Model.

Bohm's pilot-wave model (Bohm, 1952) is an attempt to supplement Process 2 by adding an extra element, not involving mind, that does the job that the mind-driven Process 1 does in the orthodox interpretation.

The main objection to Bohm's model is that it adds no testable content. It adds to the mathematical machinery of quantum theory a theoretical substructure built on a resuscitation of the classical idea of a world of point particles (atomic-sized planet-like objects). The function of his postulated world of classically conceived particles is to determine, in accordance with classical concepts, what our experiences will be. Because there is, according to Bohm's model, only one such classical world, there will be only one experience, not the infinite host of them that Process 2 seems to generate.

To make this idea work, in a way compatible with the predictions of quantum mechanics, the motion of each particle in the universe, at each instant of time, is obliged, in general, to depend sensitively on the locations of every other particle in the universe at that instant. But the location of every particle in the universe at the present instant "now" can never be known to us. So the extra "classical" structure postulated by Bohm adds no predictive power. It may give certain physicists and philosophers a warm feeling of "understanding", but this understanding can never be tested or concretely used.

I once asked Bohm how he answered Einstein's charge that his model was "too cheap". He said that he completely agreed! Notice, in this connection, that in the last two chapters of his book with Hiley, Bohm goes beyond this simple model, and tries, in terms of his ideas of implicate and explicate order, to come to grips with the deeper problems that are being considered here. These other ideas are considerably less mathematical, and much more speculative and vague, than the pilot-wave model.

Bohm appreciated the need deal more substantively with the problem of consciousness. He wrote a paper on the subject (Bohm, 1986, 1990), which ended up associating consciousness with an infinite tower of pilot waves, each one piloting the wave below. But the great virtue of the original pilot-wave model, namely the fact that it was simple and deterministic with cleanly specified solvable equations, became in lost in this infinite tower.

12. DUALISM

Scientists are free to choose which concepts they take as basic in their endeavor to describe the structure of human experience. Isaac Newton took the point-like idealizations of our visual experiences of distant planets and of tiny physical objects. This is a highly restrictive choice because it leaves out most types of human experience, such as colors, sounds, pains, efforts, evaluations, etc.

Bohr, Pauli, Heisenberg, and the other founders of quantum theory broke with Newton and took action-choosing and knowledge-acquiring human agents as fundamental. Their formulation is the one used in practical physics, and there is little likelihood that it will change in that domain. However, in other disciplines, including neuroscience, psychology, and philosophy of mind, many researchers still cling to Newton’s ideas, even though these ideas are known to fail in principle for systems---such as brains---whose activities depend sensitively on the detailed behaviors of their (cloudlike) atomic constituents.

Although scientists in different fields are to some extent free to use concepts that appear to be working for them, without regard to other scientific disciplines, many of the greatest advances in science have come from unifying the treatments of different realms of phenomena. We are now engaged a great scientific endeavor to unify the neurophysiological and psychological aspects of the thinking brain.

It is surely germane to this pursuit that investigations of the atomic underpinnings of observable phenomena led the creators of quantum theory to recognize, early in the twentieth century, the essential inadequacy of the classical concepts. These scientists brought into the dynamics, in an essential way, certain psychological aspects of the human agents, and, in particular, certain of their choices about how they will act. This shift led to highly successful mathematical formulas that link together in testable ways various psychologically described empirical realities. Yet, in spite of the obvious relevance to the mind-brain problem of such a change in basic physics, which brings conscious choices efficaciously into the causal structure of physics, to fill a dynamical gap, the inertia of nineteenth century ideas has remained so great that this highly pertinent advance in physics is still largely by ignored, or even vehemently rejected, by neuroscientists interested in the mind-brain connection.

But why should this seemingly-so-relevant advance in physics be spurned by scientist so obviously in need of it?

Contemporary physics is essentially psychophysical, hence dualistic. But dualism is seen as a bête noire by many contemporary thinkers. Hence the quantum approach is often rejected because it belongs to this despised category. But why are dualistic theories held in such contempt? There is an historical reason.

I shall begin with a brief summary, abstracted from Nahmias (2002), of the principal developments in psychology during the twentieth century.

In 1898 the introspectionist E.B. Titchener delineated the proper study of psychology as the conscious mind, defined as "nothing more than the whole sum of mental processes experienced in a single lifetime." And: "We must always remember that, within the sphere of psychology, introspection is the final and only court of appeal, that psychological evidence cannot be other than introspective evidence. "

However, the psychologist William James (1892), who used introspection extensively, but recognized a causal link of consciousness to brain process, lamented that psychology had not developed any laws: "We do not even know the terms between which the elementary laws would obtain if we had them."

J.B. Watson, emphasizing the failures of introspection to achieve reliable results, went to the opposite extreme. He began his 1913 behaviorist manifesto with the words: "Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness."

The behaviorist movement made rapid gains and in 1917 H. W. Chase wrote a summary of the year's work on "Consciousness and the Unconscious" in which he reports:

"There can be no question that consciousness is rapidly losing its standing as a respectable member of the psychologist's vocabulary. Titchener in the preface of his new book says: I have avoided the use of the word 'consciousness.'

Experimental psychology has made a serious effort to give it scientific meaning, but the attempt has failed, the word is too slippery, and so is better discarded."

Technical difficulties with behaviorism began to occur and continued to mount, but, in Nahmias's words, "It was not until Chomsky's 1959 famous review of Skinner's Verbal Behavior that the tide fully turned against trying to treat language, including reports about human experience, just like any other behavior." This turning of the tide meant that behaviorism failed precisely for the point at issue: the connection of physical process to conscious process. Yet the pariah status assigned to dualism by behaviorists lingered on after the fall of behaviorism, and it still persists today. Yet why should this bias continue after the demise of the discredited philosophy that spawned it?

Daniel Dennett (1991) gives a reason. His book "Consciousness Explained" has a chapter "Why Dualism Is Forlorn", which begins with the words:

"The idea of mind as distinct …from the brain, composed not of ordinary matter but of some other special kind of stuff is dualism, and it is deservedly in disrepute today. … The prevailing wisdom, variously expressed and argued for is materialism: there is one sort of stuff, namely matter---the physical stuff of physics, chemistry, and physiology---and the mind is somehow nothing but a physical phenomenon. In short, the mind is the brain."

Dennett then asks: "What, then, is so wrong with dualism? Why is it in such disfavor?" He answers:

"A fundamental principle of physics is that any change in the trajectory of a particle is an acceleration requiring the expenditure of energy …this principle of conservation of energy … is apparently violated by dualism. This confrontation between standard physics and dualism has been endlessly discussed since Descartes's own day, and is widely regarded as the inescapable flaw in dualism."

This argument depends on identifying "standard physics" with nineteenth century physics. But the argument collapses when one goes over to contemporary physics, in which, due the Heisenberg Uncertainty Principle, trajectories of particles are replaced by cloud-like structures, and in which conscious effort can influence brain activity without violating the laws of physics. Contemporary physical theory allows, and its orthodox von Neumann form entails, an interactive dualism. There is no valid science-based reason to reject as either unscientific or useless the conception of the human person based on the psychophysical principles of orthodox twenty-first century physics, rather than the known-to-be-false materialist principles of nineteenth century physics.

Dave Chalmers(1995) in the last chapter of the book Explaining Consciousness: The Hard Problem dismisses my quantum theory of consciousness with the words: "Consider Stapp's view, for example. Presumably when this view is filled out it will say that certain physical states P give rise to certain experiential states E, and that these states E bring about physical collapses in turn. But however the theory works, the fact that the states are experiential will be quite inessential to the story. One can imagine that a formally identical theory might be formulated from a 'God's-eye' view invoking such states E in causing such collapses, but never mentioning experience at all. So it is not easy to see how Stapp is giving experience an essential role."

This argument seems to me to be invalid. Quantum theory, as formulated by the founders, is about the structure of our streams of conscious experiences. It is about certain real things, namely our conscious experiences. "Never mentioning experience" eradicates the theory. It obliterates the entire structure by eliminating both the realities whose structural features it seeks to explain, and also an essential component of the dynamics, namely the causes of certain critical choices, which have no specified sufficient basis in the physically described world, but are asserted by the theory to originate in part in the experiential aspects of human beings. Nor can one eliminate the physical aspect: each real psychic event is an aspect of a psychophysical event whose physical aspect is an action in a mathematical structure that is a generalization of the mathematical structure of classical physics. Of course, in any theory one can replace an asserted dynamical dependence on human conscious choices by "God's Will". But in a science-based approach one seeks to push God's inscrutable will out of the description as far as possible, rather than injecting His Will into the theory in order to eliminate the causal dependence of events on our own knowable and describable choices.

This quantum theory of consciousness appears to be, indeed, exactly the sort of theory that Chalmers professes to be seeking. It takes consciousness very seriously, and it answers Chalmers' "hard problem" of "why is consciousness present at all" by making the theory not a theory of a physical world with consciousness mysteriously added on, but rather a theory about the structure of our streams of consciousness. The theory is not a pure idealism. It ties, by means of dynamical laws, the features of our streams of consciousness that we normally imagine to be due the existence of an objective physical world to a mathematical structure that is a generalization of classical mechanics. This generalization allows the mathematically described physical states to represent states of knowledge rather than states of material substance, and it has a dynamical opening that allows the psychologically described reality of "mental effort" to be causally efficacious in just the way described long ago in William James's account of volition (James, 1892).

13. SCIENCE AND REALITY.

Human beings play a singular role in Copenhagen quantum theory. Within that pragmatic framework science is viewed as a human endeavor, performed by human beings for human beings. The aim of the theory is to understand the structure of human experience for the purpose of allowing us to tailor our actions to suit our needs. What is “really out there”, supporting our mental and physical activities, is relevant only to the extent that it impacts upon the structure of human experience. All aspects of theories about “reality” that are not unambiguously linked to the content of human experience are unverifiable, hence speculative, and are thus not part of pragmatic Copenhagen science.

Still, most scientists believe that something was going on before Homo sapiens arrived on the scene, and many hold that the task of science will not be finished until we have a science-based idea of what that something was, and how our species emerged from it. Science should, from this point of view, be non-anthropocentric.

My intention in this chapter is to begin to address the question of the place of human beings in a broader non-anthropocentric setting, by building upon the foundation laid by pragmatic quantum theory, rather than by retreating to a classical mechanistic conception of man. Indeed, the approach of scientists and philosophers who base their thinking on the classical conceptualization of human brains depends on a promissory note that can never be redeemed---because it leaves a key player out.

That promise is that someday we shall be able to understand how a conscious experience---a feeling or knowing---can either be, or be a necessary consequence of, a structure built exclusively out of the elements described by classical mechanics. The classical concepts and laws entail all kinds of microscopic and macroscopic geometric, behavioral, and functional properties, but nothing in those concepts and principles can ensure or dictate that some changing arrangement of numbers assigned to space-time points, which is basically all that classical physics can ever provide, will necessarily be accompanied by, say, a “painful feeling”. Thus feelings can be only gratuitous---not rationally entailed---add-ons to any structure built solely from entities possessing only the properties specified by the logically and dynamically complete structure of classical physics.

Such psychological supernumeraries, being entailed neither dynamically nor logically, can be stripped away from the classical physics ontology without affecting the course of physical events prescribed by that theory. Hence those feelings are, within the classical physics ontology, devoid of survival value. Nor can it be argued that feelings must emerge from such classically conceived systems because we ourselves are the living proof. For we ourselves are certainly not built out of elements that conform to the highly idealized concept of atomic-sized planets that is the basis of classical physics. We, insofar as contemporary science has correctly informed us, are built out a very different kind of stuff that is more like information and tendencies for experiences to occur, than like swirling swarms of tiny planets.

It is fashionable to assert that the classical concepts are adequate because our conscious experiences can emerge from complex high-level activities of elements that conform to the classical concepts. But one must distinguish “trivial emergence” from “mystical emergence”.

Trivial emergence is the production of a complex physical behavior, such as that of a wrist watch or a weather pattern, that is rationally describable, at least in principle, in terms of behaviors of mathematical functions of the classically described variables that make up the system, and which behaviors can, moreover, be deduced, at least in principle, from the laws of classical physics.

Mystical emergence is the production of a property that does not follow rationally from the classical precepts in the way that a trivially emergent property does. Since classical physics is a fiction---real physical systems are not made of the atomic-sized planets postulated in classical physics---one cannot add properties to those specified in classical physics by simply asserting that in reality the classical properties get augmented by something not deducible from the premises. Classical physics is a (fictional) deductive system, and as such its consequences consist solely of what follows logically from its premises.

In order to get something like consciousness out of a deductive theory one must put at least the seeds of consciousness in. But all traces of consciousness have been systematically removed from classical physics. In classical physics the actions of systems are controlled by purely geometric factors: i.e., by numbers assigned to points in space-time, and by laws that relate the numbers assigned to neighboring points to each others. These laws never refer to conscious feelings, choices, intentions, or efforts.

Orthodox quantum theory, on the other hand, requires, in order to yield well defined verifiable predictions pertaining to human experiences, the existence of Process 1 actions. These actions institute in the physical world special activities that are intended to produce desired experiential feedbacks. Each such action is a dynamically efficacious element of the theory, and a link between the experiential and physical aspects of the theory. Thus quantum physics provides, as a central feature of the dynamics, an element that was formerly provided by metaphysics, namely a dynamical link between the physical attributes of an agent, which are described in geometrical terms, and experiential aspects that are described in psychological terms.

In short, quantum theory lies on a higher level of generality than classical physics because it encompasses within its internal structure aspects of our understanding of things that were formerly logically disjoint

The new understanding speaks of two processes, Processes 1 and 2. Each Process 1 action separates the prior physical state into two independent branches, “Yes” and “No”. The theory assigns a statistical weight to each branch. Subjectively, these statistical weights determine the “probabilities” that the agent will experience the “Yes” feedback or will not experience that feedback.

The simplest explanation of the meaning of these statistical properties is that “Nature chooses” either the “Yes” state or the “No” state in accordance with a “propensity” or “objective tendency” specified by the above formulas. However, it is worth noting that von Neumann himself did not explicitly specify that an “objective choice” of one branch or another actually occurs. All that the empirical evidence confirms is that our subjective experiences are “as if” this objective choice occurs. Von Neumann presumably wished to say no more.

Dirac explicitly mentions this “The Choice on the part of Nature.” I shall call it by the name Process 3. It is often called “The collapse of the wave function,” or the “Reduction of the wave packet.” It is the choice between “Yes” and “No”. I shall speak as if this latter choice/reduction really does occur, although this option is empirically indistinguishable from the option that “all subjective experiences are as if these reductions really do occur with the statistical weights specified by the theory.” The many-worlds theories mentioned above exploit this “as if” option left open by von Neumann, but the difficulty with that interpretation involves not Process 3, but, rather, the agent-controlled Process 1, which is the process that von Neumann does explicitly talk about.

Another thing left out of von Neumann’s description is the process by means of which the agent’s choice of Process 1 is made. I shall call this Process 4. A description of Process 4 is needed to expand von Neumann’s framework into an ontology, or theory of reality.

It has been amply emphasized that within the pragmatic quantum framework we take the agent’s choice of what action he or she will take to be a “free variable,” or “free choice” on the part of that agent. This is because that is how these choices enter in actual experimental practice, and also because the quantum uncertainty principle makes it impossible in principle for anyone to know enough about the microscopic details of what is happening (for example, the motions of calcium ions in the nerve terminals) to be able to predict, in general, what the Process 1 choice will be. The choice of Process 1 is thus considered to be specified by the agent who is doing the experiment. This choice will be in line with the aims and protocols of the experiment, or with the goal of some other psychologically described endeavor.

But if we now wish to go beyond the pragmatic approach and propose a theory of “what is really going on”---i.e., if we wish move on to an ontologically construed theory---then we need to have a theory about how the agent comes to make this particular choice, rather than some other choice. What are the respective roles in this choice of his or her psychologically and physically described aspects: how do mind and brain conspire to produce a definite choice for the psychophysical Process 1.

An example of a (partial) theory for Process 4 was given in Stapp (1999). That proposal is in line with the words of William James quoted above. The suggestion is that there is a purely mathematical property of the quantum state of brain that is sufficient, but not necessary, to provoke a Process 1 intervention. Thus a Process 1 intervention can occur without any conscious precursor. But it is proposed that the "Yes" outcomes of certain Process 1 actions upon brain states have a felt quality that is sufficient to cause a quick repeat of that Process 1 intervention. If the repeat action is sufficiently fast then the basic dynamical law of quantum theory entails that the answer to this next query will again be "Yes", etc. etc. leading to a repetitiously repeated "Yes", and hence to a quantum Zeno effect holding action. This holding action will tend to keep in place, against any contrary tendencies inhering in Process 2, the template for action actualized by these "yes" answers, and this will, in turn, tend to make the templated action occur.

This proposal is in line with William James's idea that the neural machinery catches the thought, but effort is needed to hold onto it. It also allows Process 1 actions to predate human life, and, indeed, all life.

14. HEISENBERG'S ONTOLOGY AND PSYCHOPHYSICAL PARALLELISM.

The official (Bohr/Copenhagen) version of quantum theory is pragmatic and epistemological, and it studiously avoids providing a traditional ontological description of what is really going on. But physicists, no matter how well conditioned they are to the idea that "what is really going on" is not the business of scientists, sometimes, relent, and want to know more than just the rules. They want to know what's actually happening.

Two non-orthodox quantum-based efforts to supply an idea of what is really happening are the Many-Worlds and Pilot-Wave interpretations described earlier. However, the huge majority of practicing quantum physicists undoubtedly lean more in the direction of Heisenberg's ideas about this.

In the chapter "The Copenhagen Interpretation" in his book Physics and Philosophy Heisenberg generally adheres to the pragmatic approach, but at one point he says "A real difficulty in the understanding of this interpretation arises, however, when one asks the famous question: But what happens 'really' in an atomic event?"

The essence of Heisenberg's answer is expressed in the following two passages:

> …the act of registration of the result in the mind of the observer. The discontinuous change in the probability function, …, takes place with the act of registration, because it is the discontinuous change in our

> knowledge in the instant of recognition that has its image in the discontinuous change in the probability function. (Heisenberg, 1958, p.55)

The point here is that the quantum formalism is a symbolic procedure that scientists use to compute expectations about future experiences on the basis of their current knowledge. Speculations about the nature of the underlying reality are not needed to apply this symbolic formalism, which resides in the minds of the scientists who use it.

But Heisenberg also opines that

> If we want to describe what happens in an atomic event, we have to realize that the word "happens"….applies to the physical not the psychological act of observation, and we may say that the transition from 'potential' to 'actual' takes place as soon as the interaction of the object with the measuring device, and thereby with rest of the world, has come into play; it is not connected with the act of registration of the result by the mind of the observer.

So, if one goes beyond the pragmatic stance and inquires about what is really happening, then Heisenberg suggests that a transition from "possible" to "actual" takes place at the device-system interface. However, that "happening" need not be described in much detail, because it is not part of the computational procedure, which is strictly pragmatic.

If, in accordance with von Neumann's work, we shift the separation between prober and probee so that the probed system becomes the brain of the observer, then the "happening" becomes a physical event in the brain of the agent.

Heisenberg's idea is that a real happening occurs somewhere. However, various placements of the separation between prober and probee are possible. Von Neumann shows how in a good measurement situation (one in which there is a tight causal linkage that properly conveys the information about the outcome at the device into the region of the brain associated with the registering of this outcome in the stream of consciousness of the observer) the pragmatic computation gives the correct answer no matter where we imagine the dividing line between prober and probee to be placed:

> it must be possible so to describe the extra-physical process of subjective perception as if it were in reality in the physical world---i.e., to assign to its parts equivalent physical processes in the objective environment, in ordinary space. (von Neumann, 1932/55, p. 419)

Notice the primacy in von Neumann's statement of the subjective process compared to the "as if" status of the equivalent objective process in the physical world.

von Neumann's mathematics shows that if the mind-brain event does occur, then the computed probability for this psychophysical event to occur---and also the effect of this psychophysical event on the state of the universe---is very nearly the same as if the perceived collapse event really did occur at the device.

This near-non-dependence of the predictions of quantum theory on whether and where nonpsychical macrophysical events occur accounts for the range of opinions of scientists on that question. Although most practical physicists prefer to imagine, with Heisenberg, that there is a macroscopic world that is roughly what it appears to us to be, it is nearly impossible to acquire evidence in support of this assertion, under the condition "and thereby with the rest of the world" specified by Heisenberg. This dearth of pertinent evidence allows the many-minds advocates to propose, in opposition to Heisenberg's ontological supposition, that no collapses occur at the devices.

These considerations exhibit what all quantum physicists are taught: efforts to go beyond "science", as specified by the Copenhagen/von Neumann rules for making prediction about future experiences on the basis of past knowledge lead to ontological possibilities between which no available data yet decides.

This absence of data that distinguishes between alternative possible ontologies opens the door to a plethora of metaphysical speculations. However, the existence of such disagreements pertaining to ontological extensions of quantum theory, hardly justifies the conclusion that the concepts of classical physics will therefore give a correct account of the role of consciousness in human behavior. A rational science-based conception of human beings must be based on the quantum rather than classical concepts because the former give testable predictions of unparalleled accuracy pertaining to the detailed structure of human experience, whereas the latter generally give predictions that are grossly out of line with that structure in cases where the observed macroscopic behavior of the system depends sensitively on the behavior of atomic-level elements.

Further pursuit of the ontological, as opposed to orthodox pragmatic, construal of quantum theory brings in the holistic features of quantum theory. That topic takes us outside the main line of this book, and is deferred to Appendix D.

15. VALUES.

This book began with the observation that what science says about what you are, and how you are connected to the rest of nature, affects the words of influential thinkers, and consequently the social milieu that undergirds both your physical being and your conscious thoughts. It affects your values, and thereby the entire fabric of your life.

Our focus so far has been upon the twentieth-century revolution in what science says about these matters. That century began with science proclaiming the materialist doctrine of a fully mechanical universe; of a universe consisting of tiny realities whose lawfully specified interactions with immediate neighbors fix, from primordial initial conditions, the entire course of history. Thoughts, ideas, and feelings need never be considered, because the dynamical rules can be stated---and their consequences fully determined in principle---without ever acknowledging the existence of such entities. But that old mechanical picture, however simple and attractive it may have seemed, cannot describe the dynamics of human brains. In that system, for reasons spelled out in detail above, quantum effects are in principle important. But the only worked-out physical theory that seems to deal adequate adequately with a thinking brain is the formulation of quantum theory devised by John von Neumann. This theory, like its classical predecessor, has a causal process that is fully determined by the interactions between tiny neighboring entities. Von Neumann calls this process by the name Process 2. However, this mechanism by itself it does not yield a complete scientific theory: it is augmented by another process, called Process 1, which injects effects of a person's thoughts and feelings directly into the theory of the workings of his or her brain. The classical mechanical laws are an approximation that systematically excludes the effects of the uncertainty principle, and hence eliminates both the need for, and the dynamical effects of, Process 1. It thereby eliminates, in principle, dynamical effects of your mind upon your brain that quantum theory naturally accommodates.

How does this revised understanding impact upon human values?

First, there is the matter of personal responsibility for one's acts. How can a person be responsible for actions that are mechanical consequences of the activities of genes acting in an externally controlled environment? No one blames a robot for its actions: its maker gets the blame. According to the mechanical conception of man, the notion that a person's mental effort can influence his actions must be recognized as an illusion, disproved by basic science, which reveals humans to be automata deluded by the absurd belief that such insubstantial and immaterial phantasms as thoughts could affect the implacable march of the material atoms.

This notion of the ineffectualness of our minds has acquired great standing in our legal, social, intellectual, institutional, and philosophical systems. However, that idea would surely be seen as absurd, apart from the belief that it follows inexorably from the basic laws of nature. Yet it certainly does not follow from the laws of contemporary physics. And the reason is not simply that determinism has been replaced by pure chance! Quantum mechanics contains a specific mechanism that in principle allows mental effort to hold at bay strong forces arising from the mechanical side of nature, and allows mental intent to influence brain processes. This epoch-making development in modern physics thus supports, at least in principle, our experience-based belief in the causal effectiveness of our mental efforts upon our physical actions, and thereby the basis of the concept of personal responsibility that is the foundation of traditional moral social life.

The second impact is perhaps more subtle. It stems from the shift from a mechanistic conception of nature to one in which the basic functional elements are knowables rather than beables. The dynamical laws are expressed in terms of a mathematical structure that expresses what is known and can become known, and that describes the effects of our efforts to learn what we are able to know. There is, in von Neumann quantum theory, an evolving state of the universe that incorporates all the knowledge of all the agents in one unified structure, and that undergoes a global change when any agent acquires new knowledge. This non-local interconnectedness has important, and highly tested, consequences that are incompatible with the mechanistic precepts of classical physics. I have not yet discussed these holistic features in this book, but they reinforce the basic idea that nature is knowledge-like and non-local, rather than machine-like with localizable causation; that we ourselves, both body and mind, are parts of a reality that, from a functional standpoint, is essentially knowledge-like. These matters lie outside the main thrust of this book, but are described in Appendices D and E.

This re-assessment of the freedom and efficacy of human volition, and of your place in nature, provides you with an image of yourself that is profoundly different from the idea that flows from classical physics. Whereas the latter portrays you as a mechanical vehicle constructed by mindless genes for a purpose even they do not know, quantum theory portrays you as a source of understanding and creativity that introduces distinctive form into an evolving universe.

This brings us to the central issue of values and self image. What are you? How do you fit in to the reality that supports your being?

How do you go about forming opinions on these matters? Do you simply accept the pronouncements of some “authority,” such as a church, a state, or a social or political group? All of these entities promote concepts about how you as an individual fit into the enduring reality that supports your being. And each has an agenda of its own, and hence its own internal biases. But then where can you find an unvarnished truth about your nature, and your place in Nature?

Science rests, in the end, on an authority that is beyond the pettiness of human ambition. It rests, finally, on stubborn facts. The founders of quantum theory certainly did not want to bring down the grand structure of classical physics of which they were the inheritors, beneficiaries, and torch bearers. It was stubborn facts that forced their hand, and made them reluctantly abandon the classical ideal of a fully mechanical universe, and turn to what perhaps should have been seen from the start as more reasonable and pertinent endeavor: create an understanding of nature that includes the human thoughts by which we know nature, and sometimes influence it. The labors of scientists endeavoring only to understand our inanimate environment produced, from its own internal logic, a rationally coherent framework within which we ourselves fit. What was falsified by objective twentieth-century science was not the core traditions and intuitions that have sustained societies and civilizations since the dawn of mankind, but rather an historical aberration, an impoverished world view within which philosophers of the past few centuries have relentlessly but fruitlessly tried to find ourselves. The failure of that deviant excursion of science must be heralded, because humans are not likely to endure in a world ruled by a conception of reality that leaves us out, or portrays us in a way that excludes our essence.

16. RECAPITULATION AND RAMIFICATIONS.

You may have found it difficult to believe yourself to be what classical physics claimed you to be, namely a blob of protoplasm constructed by protein molecules as a consequence of some freakish quirks in the laws of nature, and lodged in an essentially mindless universe where thoughts can do nothing that mindless particles have not already done. That morally corrosive picture you, and of every one of us, is still today being drummed incessantly into the heads of us all, including impressionable students and children, as the firm conclusion of science, in spite of its having been found, more than a century ago, to be incompatible with scientifically established facts.

The pervasive broadcasting of this false message---that science shows your conscious efforts to be futile---is both pernicious and scientifically unwarranted. The behaviors promoted by this dreary, debasing, and rationally incoherent mechanical image of oneself will differ significantly from the behaviors generated by a rationally coherent and empowering image of oneself as a potential instigator of reason-based action. And the acceptance of one such faulty and contrary to experience conclusion on the basis of obeisance to a supposed intellectual authority opens the way to the surrender of reason itself.

You might now say: So what’s new? I always knew my thoughts influenced my actions!

You may indeed have always known this. Your knowledge that your mental efforts can affect your bodily behavior is something you learned very early on in life, and is fundamental to your dealings with the world. However, the conflict between that intuitively known truth and the precepts of Newtonian physics produced three hundred years of philosophical turmoil that spilled over into the political, social, legal, educational, and moral arenas, and deeply affected the intellectual climate in which you are imbedded, and thereby your conception of yourself as part of the enveloping reality.

Philosophers have tried doggedly for three centuries to understand the role of mind in the workings of a brain conceived to function according to principles of classical physics. We now know no such brain actually exists: no brain, body, or anything else in the real world is composed of those tiny bits of matter that Newton imagined the universe to be made of. Hence it is hardly surprising that those philosophical endeavors were beset by enormous difficulties, which led to such positions as that of the `eliminative materialists', who hold that our conscious thoughts must be eliminated from our scientific understanding of nature; or of the `epiphenomenalists', who admit that human experiences do exist, but claim that they play absolutely no role in how we behave; or of the `identity theorists', who claim that each conscious feeling is exactly the same thing as a motion of the particles that nineteenth century science thought brains and everything else in the universe to be made of, but that twentieth century science has shown not to exist, at least as they were formerly conceived. The tremendous difficulty in reconciling causally efficacious thought with the older physics is dramatized by the fact that for many years the mere mention of "consciousness" was considered evidence of backwardness and bad taste in most of academia, including, incredibly, even psychology and the philosophy of mind.

What you are, and will become, depends largely upon your values. Values arise from self-image: from what you believe yourself to be. Generally one is led by training, teaching, propaganda, or other forms of indoctrination, to expand one’s conception of the self: one is encouraged to perceive oneself as an integral part of some social unit such as family, ethnic or religious group, or nation, and to enlarge one’s self-interest to include the interests of this unit. If this training is successful your enlarged conception of yourself as good parent, or good son or daughter, or good Christian, Muslim, or Jew, causes you to give weight to the welfare of the unit as you would your own. In fact, if well conditioned you may give more weight to the interests of the group than to the well-being of your bodily self.

In the present context it is not relevant whether this human tendency to enlarge one’s self image is a consequence of natural malleability, instinctual tendency, spiritual insight, or something else. What is important is that we human beings do in fact have the capacity to expand our image of "self", and that this enlarged concept can become the basis of a drive so powerful that it becomes the dominant determinant of human conduct, overwhelming every other factor, including even the instinct for bodily survival.

But where reason is honored, belief must be reconciled with empirical evidence. If you seek evidence for your beliefs about what you are, and how you fit into Nature, then science claims jurisdiction, or at least relevance. Physics presents itself as the basic science, and it is to physics that you are told to turn. Thus a radical shift in the physics-based conception of man from that of an isolated mechanical automaton to that of an integral participant in a non-local holistic process that gives form to the evolving universe is a seismic event of potentially momentous proportions.

The quantum concept of man, being based on objective science equally available to all, rather than arising from special personal circumstances, has the potential of undergirding a universal system of basic values suitable to all people, without regard to the accidents of their origins. With the diffusion of this Quantum Conception of Human Beings, science may fulfill itself by adding to the material benefits it has already provided a philosophical insight of perhaps even greater ultimate value.

This issue of the connection of science to values can be put into perspective by seeing it in the context of a thumb-nail sketch of history that stresses the role of science. For this purpose let human intellectual history be divided into five periods: traditional, modern, transitional, post modern, and contemporary.

During the “traditional” era our understanding of ourselves and our relationship to Nature was based on “ancient traditions” handed down from generation to generation: “Traditions” were the chief source of wisdom about our connection to Nature. The “modern” era began in the seventeenth century with the rise of what is still called “modern science” by most educated people. That approach was based on the ideas of Bacon, Descartes, Galileo and Newton, and it provided a new source of knowledge that came to be regarded by many thinkers as more reliable than tradition.

The basic idea of modern science was “materialism”: the idea that the physical world is composed basically of tiny bits of matter whose contact interactions with adjacent bits completely control everything that is now happening, and that ever will happen. According to these laws, as they existed in the late nineteenth century, a person’s conscious thoughts and efforts can make no difference at all to what his body/brain does: whatever you do was deemed to be completely fixed by local interactions between tiny mechanical elements, with your thoughts, ideas, feelings, and efforts, to the extent that they entered at all, being simply locally determined high-level consequences of the low-level mechanical process, and hence basically just elements of a reorganized way of describing the effects of the absolutely and totally controlling microscopic causes.

This materialist conception of reality began to crumble at the beginning of the twentieth century with Max Planck’s discovery of the quantum of action. Planck announced to his son that he had, on that day, made a discovery as important as Newton’s.

That assessment was certainly correct: the ramifications of Planck’s discovery were eventually to cause Newton’s materialist conception of physical reality to come crashing down. Planck’s discovery marks the beginning of the “transitional” period.

A second important transitional development soon followed. In 1905 Einstein announced his Special Theory of Relativity. This theory denied the validity of our intuitive idea of the instant of time “now”, and promulgated the thesis that even the most basic quantities of physics, such as the length of a steel rod, and the temporal order of two events, had no objective “true values”, but were well defined only “relative” to some observer’s point of view.

Planck’s discovery led by the mid-twenties to a complete breakdown, at the fundamental level, of the classical material conception of nature. A new basic physical theory, developed principally by Werner Heisenberg, Niels Bohr, Wolfgang Pauli, and Max Born, brought “the observer” explicitly into physics. The earlier idea that the physical world is composed of tiny particles (and electromagnetic and gravitational fields) was abandoned in favor of a theory of natural phenomena in which the consciousness of the human observer is ascribed an essential role. This successor to classical physical theory is called “Copenhagen quantum theory”.

This turning away by science itself from the tenets of the objective materialist philosophy lent support to Post-Modernism. That view, which emerged during the second half of the twentieth century, promulgated, in essence, the idea that all “truths” were relative to one’s point of view, and were mere artifacts of some particular social group’s struggle for power over competing groups. Thus each social movement was entitled to its own “truth”, which was viewed simply as a socially created pawn in the power game.

The connection of Post-Modern thought to science is that both Copenhagen Quantum Theory and Relativity Theory had retreated from the idea of observer-independent objective truth: science in the first quarter of the twentieth century had not only eliminated materialism as a possible foundation for objective truth, but seemed to have discredited the very idea of objective truth in science. But if the community of scientists has renounced the idea of objective truth in favor of the pragmatic idea that “what is true for us is what works for us,” then every group becomes licensed to do the same, and the hope evaporates that science might provide objective criteria for resolving contentious social issues.

This philosophical shift has had profound social ramifications. But the physicists who initiated this mischief were generally too interested in practical developments in their own field to get involved in these philosophical issues. Thus they failed to broadcast an important fact: already by mid-century, a further development in physics had occurred that provides an effective antidote to both the ‘materialism’ of the modern era, and the ‘relativism’ and ‘social constructionism’ of the post-modern period. In particular, John von Neumann developed, during the early thirties, a form of quantum theory that brought the physical and mental aspects of nature together as two aspects of a rationally coherent whole. This theory was elevated, during the forties---by the work of

Tomonaga and Schwinger---to a form compatible with the physical requirements of the Theory of Relativity.

Von Neumann’s theory, unlike the transitional ones, provided a framework for integrating into one coherent idea of reality the empirical data residing in subjective experience with the basic mathematical structure of theoretical physics. Von Neumann’s formulation of quantum theory is the starting point of all efforts by physicists to go beyond the pragmatically satisfactory but ontologically incomplete Copenhagen form of quantum theory.

Von Neumann capitalized upon the key Copenhagen move of bringing human choices into the theory of physical reality. But, whereas the Copenhagen approach excluded the bodies and brains of the human observers from the physical world that they sought to describe, von Neumann demanded logical cohesion and mathematical precision, and was willing to follow where this rational approach led. Being a mathematician, fortified by the rigor and precision of his thought, he seemed less intimidated than his physicist brethren by the sharp contrast between the nature of the world called for by the new mathematics and the nature of the world that the genius of Isaac Newton had concocted.

A common core feature of the orthodox (Copenhagen and von Neumann) quantum theory is the incorporation of efficacious conscious human choices into the structure of basic physical theory. How this is done, and how the conception of the human person is thereby altered, is something every well informed person ought to know about, for conception of self is the basis of values and hence of behavior.

It is curious that some physicists want to improve upon orthodox quantum theory by excluding “the observer”, who, by virtue of his subjective nature, must, in their opinion, be excluded from science. That stance is maintained in direct opposition to what would seem to be the most profound advance in physics in three hundred years, namely the overcoming of the most glaring failure of classical physics, its inability to accommodate us, its creators. The most salient philosophical feature of quantum theory is that the mathematics has a dynamical gap that, by virtue of its intrinsic form, provides a perfect place for Homo sapiens as we know and experience ourselves.

Contemporary physical theory entails no determinism that curtails your capacity to choose your actions. Instead, it institutes uncertainties that break the mechanical determinism of classical physics. Yet this downfall of determinism does not lead to unfettered randomness! Our conscious choices, controlled by no known law of nature, can instigate interventions that influence, via the laws of physics, the course of physical events. This quantum conception of the mind-brain connection is compatible with your normal intuitions about your nature, with much empirical data, and with William James's conclusions about how volition works.

The effectiveness of conscious effort is not some illusion, proved by science to be a hoax or a fraud. You need not be confused by the contradiction inherent in striving to achieve for a goal while believing the efficacy of your will to be an illusion. Your capacity to influence your actions by willful effort is your birthright. But you can lose it if you allow yourself to be coerced into doubting you possess it by a fiction masquerading as science. Few things are ultimately more detrimental to our lives, and to the progress of humanity, than the incessant defeatist din that proclaims to us, and to our children, on the basis of inapplicable seventeenth century precepts, that we are helpless mechanical cogs in an essentially mindless universe.

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References.

Bell, J. S. 1964: On the Einstein-Podolsky-Rosen paradox. Physics 1 195-200.

Bohm, D. 1952: A suggested interpretation of quantum theory in terms of hidden variables. Physical Review, 85, 166-179.

Bohm, D. J. 1986: A new theory of the relationship of mind to matter. The Journal of the American Society for Psychical Research,
80, 113-135.

Bohm, D. J. 1990: A new theory of the relationship of mind to matter. Philosophical Psychology, 3, 271-286.

Bohm, D, & Hiley, D.J. 1993: The Undivided Universe. London and New York: Routledge.

Bohr, N. 1934: Atomic Theory and the Description of Nature. Cambridge: Cambridge University Press.

Bohr, N. 1935: Can quantum mechanical description of physical be considered complete? Physical Review 48, 696-702.

Bohr, N. 1958: Atomic Physics and Human Knowledge. New York: Wiley.

Bohr, N. 1963: Essays 1958/1962 on Atomic Physics and Human Knowledge. New York: Wiley.

Bunge, M. 1967: The turning of the tide. In M. Bunge (ed.), Quantum Theory and Reality. New York: Springer-Verlag New York Inc.

Chalmers, D. J. 1995: Response. In J. Shear (ed.), Explaining Consciousness: The Hard Problem. Thorverton UK: Academic.

Chase, H. W. 1917: Consciousness and the unconscious. Psychological Bulletin 14, 7-11.

Chomsky, N. 1958: A review of B.F. Skinner's Verbal Behavior. Language 35, 26-58.

Dennett, D. C. 1994: Dennett, in Samuel Guttenberg (ed.), Blackwell Companion to Philosophy of Mind. Oxford: Blackwell.

Dennett, D. C, 1991: Consciousness Explained. Boston: Little, Brown and Company.

Einstein, A., Podolsky, B. & Rosen, N. 1935: Can quantum mechanical description of physical be considered complete? Physical Review 47, 777-780.

Einstein, A. 1951: Remarks to the essays appearing in this collected volume. In P. A. Schilpp (ed.), Albert Einstein: Philosopher-Physicist.
New York, Tudor.

Haag, R. 1996: Local Quantum Physics. Berlin: Springer

Hagen, S., Hameroff, S. & Tuszynski, J. 2002: Quantum computation in brain microtules: Decoherence and biological feasibility. Physical Review E65, 061901-1 – 061901-11.

Hameroff, S. & Penrose, R. 1996: Orchestrated reduction of quantum coherence in brain microtubules: a model for consciousness. J. Consciousness Studies 3, 36-53.

Heisenberg, W. 1958a: The representation of Nature in contemporary physics. Daedalus 87, 95-108.

Heisenberg, W. 1958b: Physics and Philosophy. New York: Harper, James, W. 1890: The Principles of Psychology Vol. II. New York: Dover.

James, W. 1892: Psychology: the briefer course. In William James: Writings 1879-1899. New York: Library of America (1992).

John, E. R. 2003: A field theory of consciousness. Consciousness and Cognition 10, 184-213.

Joos, E. 1996: Introduction. In D. Giulini (ed.) Decoherence and the Appearance of aClassical World in Quantum Theory. Berlin: Springer.

Misra, B. and Sudarshan, E.C.G. 1977: The Zeno's paradox in quantum theory. Journal of Mathematical Physics 18: 756-763.

Nahmias, E. A. 2002: Verbal reports of the contentents of consciousness: reconcidering the introspectionist methodology. http://psyche.cs.monash.edu.au/v8/psyche-8-21-nahmias.html

Ochsner, K.N. & Silvia A. Bunge, James J. Gross, and John D.Gabrieli 2002: Rethinking feelings: an fMRI study of the cognitive regulation of emotion. J. Of Cognitive Neuroscience, 14:8, 1215-1229.

Pashler, H. 1998: The Psychology of Attention. Cambridge, MA: MIT Press.

Penrose, R. 1989: The Emperor's New Mind. New York: Oxford.

Penrose, R. 1994: Shadows of the Mind. New York: Oxford.

Schwartz, J. & Begley, S. 2002: The mind and the brain: neuroplasticity and the power of mental force. New York: Harper-Collins.

Schwartz, J., Stapp, H. & Beauregard, M 2003: The volitional influence of the mind on the brain, with special reference to emotional self regulation. In M. Beauregard (Ed.), Consciousness, Emotional Self-Regulation and the Brain. [Advances in Consciousness Research Series]. Amsterdam & New York: John Benjamins.

Schwartz, J., Stapp, H. & Beauregard, M. 2004, Quantum physics in neuroscience and psychology: a neurophysical model of mind/brain interaction. Phil. Trans. Royal Society: Biology Section. [http://www-physics.lbl.gov/~stapp/stappfiles.html]

Searle, J. 2000: Consciousness, free action, and the brain. J. of Consciousness Studies Vol. 7 No. 10, 3-22.

Shimony, A. 1993: Natural Science and Metaphysics (Vol 2) Search for a Naturalistic World View. Cambridge: Cambridge University Press.

Stapp, H.P. 1971: S-matrix interpretation of quantum theory. Phys. Rev. D3, 1303-1320.

Stapp, H.P. 1979: Whiteheadian approach to quantum theory and generalized Bell's theorem. Foundations of Physics, 9, 1-25.

Stapp, H.P. 1993: Mind, Matter, and Quantum Mechanics, First Edition (Spinger-Verlag).

Stapp, H.P. 1997: Science of Consciousness and the Hard Problem. The Journal of Mind and Behavior. 18 (2-3), 171-194.

Stapp, H.P. 1999: Attention, Intention, and Will in Quantum Physics, Journal of Consciousness Studies, 6 (8-9), 143-164.

Stapp, H.P. 2001: Quantum Theory and the Role of Mind in Nature. Foundations of Physics, 31, 1465-1499.

Stapp, H.P. 2002: The basis problem in many-worlds theories. Can. J. Phys, 80, 1043-1052.

Stapp, H.P. 2004a: Mind, Matter, and Quantum Mechanics, Second Edition (Spinger-Verlag).

Stapp, H. P. 2004b: Quantum approaches to consciousness, in Cambridge Handbook of Consciousness, eds. M. Moskovitch & P. Zelazo.To appear in 2005, [http://www-physics.lbl.gov/~stapp/stappfiles.html]

Stapp, H.P. 2004c: A Bell-type theorem without hidden variables. Amer. J. Phys. 72, 30-33.

Tegmark, M. 2000: Importance of quantum decoherence in brain process. Physical Review E61, 4194-4206.

Titchner, E. B. 1898: An outline of Psychology. New York: Macmillan

Watson, J. B. 1913: Psychology as the behaviorist views it. Psychology Review 20, 158-177.

Wigner, E. 1961: The probability of the existence of a self-reproducing unit. In M. Polyani (ed.) The Logic of Personal Knowledge. London: Routledge and Paul.

Von Neumann, J. 1955/1932: Mathematical Foundations of Quantum Mechanics. Princeton: Princeton University Press. (Translated by Robert T. Beyer from the 1932 German original, Mathematiche Grundlagen der Quantummechanik. Berlin: J. Springer)

Zeh, H.D. 1996: The program of decoherence: ideas and concepts. In D. Giulini (ed.) Decoherence and the Appearance of aClassical World in Quantum Theory. Berlin: Springer.

Zurek, W. H. 2002: Decoherence and the transition from quantum to classical---revisited. Los Alamos Science, November 27, 2-25.
arXiv:quant-ph/0306072.

APPENDIX A. EMPIRICAL SUPPORT FROM PSYCHOLOGY.

Much experimental work on attention and effort has occurred since the time of William James. That work has been hampered by the apparent nonexistence of any physical theory that rationally explains how our conscious experiences could actually influence activities in our brains. The behaviorist approach, which dominated psychology during the first half of the twentieth century, and which essentially abolished in this field the use not only of introspective data but also of the very concept of consciousness, was surely motivated in part by the fact that consciousness was excluded from any role in brain dynamics by the physics of the nineteenth century. The new physics had not yet been created at the time of the birth of the behaviorist movement.

The admitted failure of the behaviorist program led to the rehabilitation of “attention" during the early fifties, and many hundreds of experiments have been performed during the past fifty years for the purpose of investigating empirically those aspects of human behavior that we ordinarily link to our consciousness.

Harold Pashler's 1998 book The Psychology of Attention describes a great deal of this empirical work, and also the intertwined theoretical efforts to understand the nature of an information-processing system that could account for the intricate details of the empirical data. Two key concepts are the notions of “Attention” and of a processing “Capacity”. The former is associated with an internally directed selection between different possible allocations of the available processing “Capacity”. A third concept is “Effort”, which is linked to incentives, and to reports by subjects of “trying harder”.

Pashler organizes his discussion by separating perceptual processing from post-perceptual processing. The former covers processing that, first of all, identifies such basic physical properties of stimuli as location, color, loudness, and pitch, and, secondly, identifies stimuli in terms of categories of meaning. The post-perceptual process covers the tasks of producing motor actions and cognitive action beyond mere categorical identification. Pashler emphasizes [p. 33] that “the empirical findings of attention studies specifically argue for a distinction between perceptual limitations and more central limitations involved in thought and the planning of action.” The existence of these two different processes, with different characteristics, is a principal theme of Pashler's book [p. 33, 263, 293, 317, 404]

In the quantum theory of mind-brain being described here there are two separate processes. First, there is the unconscious mechanical brain process called Process 2. As discussed at length in my earlier book, Mind, Matter, and Quantum Mechanics, this brain processing involves dynamical units that are represented by complex patterns of neural activity (or, more generally, of brain activity) that are “facilitated” (i.e., strengthened) by use, and are such that each unit tends to be activated as a whole by the activation of several of its parts. The activation of various of these complex patterns by cross referencing---i.e., by activation of several of its parts---coupled to feed-back loops that strengthen or weaken the activities of appropriate processing centers, appears to account for the essential features of the mechanical part of the dynamics in a way not greatly different from that of a classical model, except for the creation of a superposition of a host of parallel possibilities that according to the classical concepts could not exist simultaneously.

The second process, von Neumann's Process 1, must be added to the dynamics in order to extract from the mathematics any prediction about anything knowable. This process selects some particular question, whose answer “Yes” or “No” can then become known to us, from among the continuum of possible questions generated by Process 2

Two kinds of Process 1 actions are possible. One possible kind would be determined by brain activity alone, perhaps with an essentially passive consent, and involve a single isolated event. This would be the kind of the action associated with James’s assertion that “No object can catch our attention except by the neural machinery.” A second possible kind of Process 1 action would be triggered by an active felt quality of some prior experience. Thus an earlier increment of knowledge arising from a “Yes” feedback to a prior question could include a feeling that this question should be quickly asked again. Such a Process 1 action could, within the quantum framework, induce a rapid repetitious sequence of similar actions that would activate a quantum Zeno effect. This second kind of Process 1 action is allowed in principle because the rules of contemporary quantum do not specify what determines the sequence of Process 1 events, while they do explicitly introduce experiential realities, per se, into quantum dynamics.

The “perceptual” aspect of brain process discussed by Pashler can be associated with Process 2, and also with the essentially passive Process 1, whereas the higher-level processing that Pashler identifies can be associated with the active mode of Process 1, which involves a sequence of effortfully sustained Process 1 purposeful actions.

This quantum conception of brain dynamics seems to accommodate all of the perceptual aspects of the data described by Pashler as automatic or near automatic processing. But it is the high-level processing, which is linked to active mental effort, that is of prime interest here. The data pertaining to this second kind of process is the focus of part II of Pashler's book.

Active Process 1 intervention has, according to the quantum-physics-based theory described here, a distinctive form. It consists of a sequence of purposeful actions, selected out from a morass of brain-created possibilities by mindful choices, with the property that the rapidity of these actions can be increased with effort. Effort-induced speed-up of the rate of occurrence of these events can, by means of the quantum Zeno effect, keep attention focused on an intention. It is reasonable to suppose that any agent has at any time a finite capacity of events per second.

Examination of Pashler's book shows that this quantum-physics-based theory accommodates naturally all of the complex structural features of the empirical data that he describes. He emphasizes [p. 33] a specific finding: strong empirical evidence for what he calls a central processing bottleneck associated with the attentive selection of a motor action. This kind of bottleneck is what the quantum-physics-based theory predicts: the bottleneck is precisely the single linear sequence of Process 1 actions that quantum theory is built upon.

The sort of effect that Pashler finds is illustrated by a result he describes that dates from the nineteenth century: mental exertion reduces the amount of physical force that a person can apply. He notes that “This puzzling phenomena remains unexplained.” [p. 387]. However, it is an automatic consequence of the physics-based theory: creating physical force by muscle contraction requires an effort that opposes the physical tendencies generated by Process 2. This opposing tendency is produced by the quantum Zeno effect, and is roughly proportional to the number of bits per second of central processing capacity that is devoted to the task. So if part of this processing capacity is directed to another task, then the applied force will diminish.

An interesting experiment mentioned by Pashler involves the simultaneous tasks of doing an IQ test and giving a foot response to rapidly presented sequences of tones of either 2000 or 250 Hz. The subject's mental age, as measured by the IQ test, was reduced from adult to 8 years. Effort can be divided, but at a maximal level there is a net total rate of effortful Process 1 actions.

Another interesting experiment showed that, when performing at maximum speed, with fixed accuracy, subjects produced responses at the same rate whether performing one task or two simultaneously: the limited capacity to produce responses can be divided between two simultaneously performed tasks. [p. 301]

Pashler also notes [p. 348] that ``Recent results strengthen the case for central interference even further, concluding that memory retrieval is subject to the same discrete processing bottleneck that prevents simultaneous response selection in two speeded choice tasks.''

In the section on ``Mental Effort'' Pashler reports that ``incentives to perform especially well lead subjects to improve both speed and accuracy'', and that the motivation had ``greater effects on the more cognitively complex activity''. This is what would be expected if incentives lead to effort that produces increased rapidity of the events, each of which injects mental intention into the physical process.

Studies of sleep-deprived subjects suggest that in these cases ``effort works to counteract low arousal''. If arousal is essentially the rate of occurrence of conscious events then this result is what the quantum model would predict.

Pashler notes that ``Performing two tasks at the same time, for example, almost invariably... produces poorer performance in a task and increases ratings in effortfulness.'' And ``Increasing the rate at which events occur in experimenter-paced tasks often increases effort ratings without affecting performance''. ``Increasing incentives often raises workload ratings and performance at the same time.'' All of these empirical connections are in line with the general principle that effort increases the rate of conscious events, each of which inputs a mental intention, and that this resource can be divided between tasks.

A more extended discussion of the Pashler data from the quantum point of view can be found in Stapp (2001) and in Schwartz, Stapp, and Beauregard (2003)

After analyzing various possible mechanisms that could cause the central bottleneck, Pashler [p.307-8] says ``the question of why this should be the case is quite puzzling.'' Thus it is noteworthy that this bottleneck, and its basic properties, follow naturally from the same laws that explain the empirical evidence in the fields of classical and quantum physics.

APPENDIX B. EMPIRICAL SUPORT FROM NEUROSCIENCE.

The most incisive data in the study of the mind-brain connection will probably be the data collected by neuroscientists who monitor the activity of the brains of subjects subjected to various kinds of stimuli. Human subjects are, by means of linguistic communication, open to particularly informative empirical inquiries.

There is by now a large amount of data supporting the core idea of the quantum model, namely the existence, in association with consciousness, of characteristic oscillatory modes of neural activity that extend over macroscopic portions of the brain. For a summary see the article of E. Roy John (2003). In the quantum model developed here the oscillatory pattern of brain activity associated with a conscious effort is a template for action that will, if sustained, tend to bring into being the intended effect. The fact that such brain correlates of consciousness exist and have this macroscopic oscillatory structure is not in itself strong evidence in favor of the quantum model. However, failure to find such structures would be strong evidence against this model. Hence one important test has been passed.

Perhaps partially under the influence of the classical idea that reality is built out of small localized parts that interact only with their neighbors, early neuroscientists had considered models of the mind-brain connection in which the cause of an individual conscious thought was far more localized---for example in the firing of individual neurons or small groups of neurons. Within that classical framework the proposition that an atomic thought should correspond to, or be, a spatially extended oscillatory motion is somewhat unnatural. But in quantum theory the extended character of the correspondence is an automatic consequence of the (necessarily) non local character of the Process 1 action. A Process 1 action that acts at a point would dump an infinite amount of energy into the brain and literally cause it to explode. Hence the Process 1 action must act over an extended region. The oscillatory character is a consequence of the fact that in quantum theory endurance resides in oscillatory activity, not in static being.

The paper of John also cites data that support the basic feature of the quantum model that the “stream of consciousness” consists of a sequence of discrete moments, or “perceptual frames,” each persisting for a fraction of a second. This feature is in line with the quantum model, in which a person’s stream of consciousness is the psychological aspect of a sequence of psychophysical events that are key dynamical components of the behavior of his or her mind-brain.

John’s paper speaks also of a “comparator”. John says that “Only an unknown fraction of the neural activity at any moment may possess informational utility for the control of adaptive behavior, which is how the brain contributes to survival. Some process beyond mere synchrony or nonrandomness must be invoked if the brain is to identify the relevant, informationally meaningful activity which is to be combined into an integrated percept. Further, what mechanism parses time into discontinuous intervals, ‘closes’ the microstate, and assesses the meaning of the different neuronal events which occur within the duration of the ‘perceptual frame’?”

John goes on to say: “The global population of coherent neurons must be evaluated, irrelevant activity (“noise”) excluded, and informationally significant activity (‘signal”) bound into a percept or ‘qualia’, a subjective instant of awareness. Otherwise, consciousness would be overwhelmed by a continuous sensory barrage.”

John’s “comparator” does what the quantum Process 1 does: it picks out of a continuum of incipient possible templates for action the one template that actually occurs in association with a moment of experience.

John finds new neurophysiological evidence for the existence of his “comparator” process, or at least of the physical and experiential consequences of such a process. In trained animals, a meaningful input signal evokes of a widespread “late” positive peak provided the conditioned response is elicited, but no such peak when performance fails. This late component is widespread and “was released from a nonsensory specific representational system” “This system, established by previous learning, reflected contributions of memory, motivation, and affect related to stimuli.” In conscious human patients an electrical stimulation timed to disrupt the analogous late peak blocked perception. This late peak, which John associates with his “comparator”, seems to correspond to the actualization of the template for action specified by Process 1.

Within a classical framework one is obligated, in principle, to provide some micro-causal account of how all of these factors and features, memory, motivation, etc., can be represented by classically described brain activity, and how these features can then deterministically cause the activation of the widespread coordinated brain behavior, and also the associated conscious experience. But, according to the precepts of quantum physics, a strictly deterministic account is impossible in principle, particularly in cases (such as those examined by John) of ambiguous input stimuli where a choice between one or the other of two trained responses is made.

It is clearly impossible in practice to know where every one of the calcium ions is going. So a classical solution is unachievable, both in practice and in principle. Quantum theory exploits this limitation in principle. Given the failure in principle of mechanistic determinism, quantum theory takes our conscious choices and experience feedbacks to be in the theory what they are in actual empirical practice, namely the empirical inputs and feedbacks. Quantum theory provides a rationally coherent practical alternative to the failed seventeenth century program for science. Considering the fact that physics constitutes the model or paradigm of scientific practice, it is bizarre that the intrusion of causally efficacious mind should be accepted in the basic science of mindless atoms, but excluded from the basic science of conscious brains.

John considers the possibility of going over to a quantum mechanical approach but says that “quantum mechanical proposals seem implausible and unlikely.” The reason he gives is that “There is no evidence that quantum mechanical processes can apply to slow processes which transpire in brains in times on the order of milliseconds and involve many cubic centimeters of cells at body temperature.” But the burden of proof is on the other side. Quantum physics must be used in principle unless there is reason why the uncertainty principle can be ignored. What is really implausible and unlikely is the idea that the dynamics of the mind-brain system can be adequately understood in terms of the micro-causal principles of classical physics that are known to be inadequate for key dynamical elements of brains (e.g., nerve terminals) and that leave out a key part of the mind-brain system, namely the mind. If one incorporates mind in the way specified by quantum theory then mind can have a large effect on brain process that involve many cubic centimeters of cells at body temperature, and that transpire in times on the order of milliseconds. It is the size of the effects of the uncertainty principle that sets limits on the effects of mind. In conscious human brains the effects of the uncertainty principle are in principle large because they are large in the dynamics of the nerve terminals, and uncertainties at the microscopic level tend to increase as they propagate up to the macroscopic level.

Of course, there are trillions of nerve terminals. If there is massive parallel processing then the uncertainties arising at the level of the individual stochastic process can be significantly reduced. Indeed, much of our behavior, although resting on a stochastic dynamics, is effectively deterministic. But in cases where habit and training do not suffice to dictate a well determined response, the stochastic underpinnings can resurface, and provide, in principle, room for a Process 1 intervention that is not deterministically fixed by the mathematically described state of the world.

Appendix C: The Discreteness Problem in Many Worlds Theories.

In a Many Worlds (or Many Minds) approach the quantum state under consideration is the state of the whole universe. It is represented by a generalization of an N-by-N matrix. The rows and columns of this “matrix” are labeled not by a set of integers (i.e., whole numbers), but rather by an index, here called I that specifies the location of every particle in the universe. (Actually, one must consider also “fields”, but I shall ignore that complication in his account.) Subsystems are also represented.

The physical system S is represented by a “matrix” S(I,I’), where I specifies a possible location for every “particle” in the classical conception of the system, and so does I’. The “diagonal” elements are those for which I = I’. The far off-diagonal elements are suppressed by the interaction with the environment, but the slightly off-diagonal elements remain generally nonzero, and they lock the whole near-diagonal structure together. The region where S(I,I) is significantly different from zero remains large, even after the effects of interaction with the environment are taken into account. In a world governed exclusively by Process 2 from the time of the big bang there will be a huge smearing effect. Consequently, this nearly diagonal portion of the state cannot be expected to be broken up into a collection of different, isolated regions that could be associated with different experiences. Therefore, the separation of the state of the universe into a suitable countable set of states seems to require something besides Process 2. Anyone who claims that the Schroedinger evolution (Process 2) alone is sufficient to separate this state into a countable set of components corresponding to different experiences needs to explain how this comes about.

The real situation involves a space of an infinite number of dimensions, but the discreteness problem can be illustrated in a simple model having just two dimensions. Take a sheet of paper and put a point on it. (Imagine that your pencil is infinitely sharp, and can draw a true point, and perfectly straight lines of zero width.) Start drawing straight lines out from the point in different directions. With an infinitely sharp pencil your could draw lines in different directions for billions of years, at one line a femto-second, and not come even close to using up the set of all possible directions. However, the rules of quantum theory demand in this two dimensional case that some one particular direction, (together with the one perpendicular to it) be picked out from this continuous infinity of possible directions as preferred to all the others. But how is such an incredibly precise choice determined by this continuous Process 2?

But why is this choice of a discrete basis so essential? Let me explain.

If you have just a countable set of states then you could, for example, assign probability ½ to the first state, probability ¼ to the second state, probability ⅛ to the third, and so on, and the total probability will add to one (unity), as a sum of probabilities should. But if the probability S(I,I) is a continuous function of I, as it would be if only process 2 were present, and there were a distinct experience for each value of I, and S(I,I) were non-zero for some value of I , then S(I,I) would necessarily be larger than some (perhaps very tiny) non-zero number, say e, in some finite region. (This follows from the continuousness of S(I,I), and the fact that S(I,I) must be a positive number or zero.) But there are an infinite number of possible values of I in any finite interval, and if each one represents a real existing different experience, then the total probability for an experience to occur would be at least infinity times e, or infinity.

The main idea of quantum theory is to use a generalization of the theorem of Pythagoras to resolve this problem. That theorem says that the sum of the squares of the two shorter sides of a right triangle is equal to the square of the longer side. This rule generalizes to a figure in a space of a countable number of dimensions in the following way: If a displacement of unit length is a sum of a set of displacements each perpendicular to every other one, then the sum of the squares of the lengths of these displacements is one (unity). Using this law we can guarantee that probabilities of the different experience possible in any given situation will add to unity (i.e., to one) if we assert that the different possible experiences correspond to a set of mutually perpendicular directions in the space of possibilities. But any one preferred set of directions is an infinitely small fraction of the set of all possibilities. So the main problem in principle in the construction of a satisfactory quantum theory is: How is a particular set of perpendicular directions in the space of all possibilities singled out from all other possible sets?

The interaction of system with its environment reduces the set allowed possibilities drastically. But one is left not with a set of exactly classical possibilities but with a collection of quasi-classical possibilities each overlapping and interlocking with its near neighbors. The problem of showing that this structure separates, by itself, in some definite way into a countable set of components each corresponding both to a distinct experience and to a different subset of some set of perpendicular directions (in the Hilbert space) is the problem lurking behind the Zurek's very true words "Much remains to be done."

Appendix D: Ontology and Holistic Features

The focus of this book has been the nature of the connection between mind and brain, as seen from the perspective of orthodox contemporary physics. This perspective focuses on "knowables", rather than on ideas about what exists apart from its capacity to be known. Yet if we want to say more about the nature of our own being then it may be necessary to take human knowledge to be not the foundation of all science, but rather an aspect of a deeper reality

The pragmatic stance of orthodox quantum theory tends to protect physics, as it is practiced, from such "deeper questions". However, Einstein succeeded it opening a tiny crack in the Copenhagen armor. That defense depends crucially on the idea that if the setting-in-place of one Process 1 probing action precludes, physically, the setting-in- place of a second, alternative, Process 1 probing action, then the existence, simultaneously, of definite answers to both of the two probing questions is forbidden. This restriction is linked to the fact that the quantum mathematics is structurally unable to represent, simultaneously, definite answers to both queries.

In 1935 Albert Einstein, together with two younger colleagues, Boris Podolsky and Nathan Rosen, wrote what is perhaps the most discussed scientific paper of the twentieth century. Entitled Can quantum mechanical description of physical reality be considered complete? (Einstein, 1935), the paper argues that the Copenhagen quantum theory does not give a complete description of physical reality. This argument was ultimately found to fail. However, the paper opened the way to follow-up papers by Niels Bohr (1935) and John Bell (1964) that led eventually to the conclusion that any world that obeys the computational rules of quantum mechanics must manifest holistic features that are completely alien to the mechanical precepts of classical physics. These features, although tangential to the issue of the mind-brain connection that is the focus of this book, are important to an understanding of our place in Nature. They entail that our streams of consciousness are part of a world of knowables that is far more integrated and connected than what any local-mechanistic world could allow.

The Einstein argument is based on an examination of correlations between certain events that can occur at essentially the same time in laboratories that lie far apart

A simple classical example of a correlation between events occurring at essentially the same time in far-apart laboratories is this. Suppose one has a pair of balls, one red, the other green. Suppose one loads them into two cannons, and fires them in opposite directions into two far-apart laboratories, in which they will be caught and examined. The colors found in the two regions will obviously be correlated: if red is found in one lab then green will be found in the other, and vice versa. There is nothing strange or peculiar about a correlation of this kind.

The simplest quantum example is similar, and is again not in itself a problem. Suppose one lets two atoms interact in a certain way and sends them to two far-apart laboratories, where they will be caught and examined by two devices, which are rigged to flash either a red light or a green light, depending on which of two alternative possible outcomes the device records. If the interaction is appropriate (i.e., if the atoms are placed in a so-called singlet state), and the devices are appropriately constructed, then we can create a situation very similar to the one with the two cannon balls: quantum mechanics will predict that if a red light flashes in one laboratory then a green light flashes in the other, and vice versa. Many experiments of this kind have been performed, and the predictions of quantum theory are confirmed to within experimental error.

Each of the devices in the quantum experiments just mentioned has a preferred direction, which is perpendicular to the common line of flight of the two atoms. These two directions can be rotated around this line of flight. The result just quoted---a red light in one lab strictly correlated with green light in the other---holds if the directions associated with the two devices are the same. If, on the other hand, one direction is rotated by 90^{o} relative to the other, then the correlation completely disappears: red in one lab is equally likely to be accompanied by red or green in the other.

This experimental set-up is, logically, essentially the one considered by Einstein, Podolsky, and Rosen. The argument that they erected upon these unremarkable predictions of quantum theory produced consternation in Copenhagen. Bohr's close colleague, Leon Rosenfeld (1967) described the situation as follows:

> "This onslaught came down upon us like a bolt from the blue. Its effect on Bohr was remarkable. We were then in the midst of grouping attempts at exploring … A new worry could not come at a less propitious time. Yet as soon as Bohr had heard my report of Einstein's argument, everything else was abandoned: we had to clear up such a misunderstanding at once. We should reply by taking up the same example and showing the right way to speak about it. Bohr immediately started dictating to me the outline of such a reply. Very soon, however, he became hesitant: "No, this will not do,…"… Eventually he broke off with the familiar remark that he "must sleep on it." The next morning… The real work now began in earnest: day after day, week after week, …"

What was Einstein's argument? What set off this huge commotion, which persists even to this day?

Let one of the two laboratories be called the nearby lab, the other the faraway lab, and consider what the agent in the nearby lab can know about the outcome in the faraway lab under two alternative possible conditions. In the first case the direction of the faraway device is set in one way; in the second case this direction is rotated by 90^o. The nearby experimenter can line up his device with either one or the other of the two alternative possible settings of the faraway device, and then by looking at the nearby outcome, Red or Green, can know---by means of the exact correlation of Red with Green when the directions in the two labs agree---what the faraway outcome for the parallel setting faraway must be.

Of course, the nearby experimenter can actually do only one or the other of the two alternative possible nearby experiments, and hence can actually know no more about the faraway outcomes in two alternative possible cases than quantum theory allows. On the other hand, he can freely choose either one or the other of the two settings here, and thereby find out what the faraway outcome will be for the parallel setting there.

Now it seems reasonable to assume, on the basis of the Special Theory of Relativity, that the free choice made in the nearby lab cannot influence, essentially instantaneously, the outcome, Red or Green, of the experiment performed at essentially the same instant far away. The real experiments, performed to test the validity of the predictions of quantum theory in this context, are set up so that, on the scale defined by information transfers at the speed of light, the faraway outcome occurs at essentially the same moment as, or even earlier than, the choice of probing action in the nearby lab. But if the choice made by the nearby experimenter cannot disturb in any way the faraway outcome then both of the two faraway outcomes would seem to exist, because either one can be become known by exercising a choice that can have no effect on that faraway outcome. Thus it seems that the outcomes of both of the alternative possible faraway measurements must actually exist, even though the quantum mathematics can accommodate an answer to only one or the other of the two alternative possible queries. This led Einstein to the conclusion that quantum mechanical description is incomplete.

Einstein and his colleagues formulated this argument in a logically tight way.

Because they want to prove that quantum mechanical description of physical reality is incomplete Einstein and Co. need a sufficient condition for the existence of a “physical reality”. They introduce this needed criterion of physical reality as follows: “If, without in any way disturbing a system we can predict with certainty (i.e., with probability equal to unity) the value of a physical property, then there exists an element of physical reality corresponding to that property.”

There is some vagueness here in the meaning of “we can predict”. Does it mean “we can actually predict” or merely “we can make a choice of action that will allow us to predict.”

Einstein and his co-workers dealt with this ambiguity by admitting that:

> “one would not arrive at our conclusion if one insisted that two or more physical quantities can be regarded as simultaneous elements of reality only when they can be simultaneously measured or predicted. On this point of view, since either one or the other, but not both simultaneously, of the quantities P and Q can be predicted, they are not simultaneously real. This makes the reality of P and Q depend upon the process of measurement carried out on the first system, which does not disturb the second system in any way. No reasonable definition of reality could be expected to permit this.”

To apply this argument to our case replace P by “the outcome, Red or Green, of the faraway probing action if the setting of the direction of the faraway device is zero degrees”, and Q by “the outcome, Red or Green, of the faraway probing action if the setting of the direction of the faraway device is ninety degrees.”

Thus the crux of Einstein’s argument is the observation that the natural Copenhagen reply “what is physically real depends on what is actually done”, would make what is physically real in the faraway lab depend upon what we freely choose to do at the essentially the same instant (or later) in the nearby lab.

The essence of Bohr's reply (Bohr, 1935) is the following passage:

> From our point of view we now see that the wording of the above-mentioned criterion of physical reality proposed by Einstein, Podolsky, and Rosen contain an ambiguity as regards the meaning of the expression "without in any way disturbing the system." Of course there is in a case like that just considered no question of a mechanical disturbance of the system under investigation during the last critical stage of the measuring procedure. But even at this stage there is essentially the question of an influence on the very conditions which describe the possible types of predictions regarding the future behavior of the system. (Bohr's italics.) Since these conditions constitute an inherent element of any phenomenon to which the term "physical reality" can be properly attached, we see that the argumentation of the above-named authors does not justify their conclusion that quantum-mechanical description is essentially incomplete.

If Bohr's argument strikes you as obscure, then you are not alone. Many philosophers and physicists have found Bohr's reply unconvincing, and have concluded that Einstein won the debate. Bohr himself says, in his contribution to the Einstein volume (Bohr, 1951, p. 234), "Reading these passages, I am deeply aware of the inefficiency of expression which must have made it very difficult to appreciate the trend of the argumentation…." That may be an understatement.

But one feature of Bohr's answer does come across clearly: his reply rejects, at some level, Einstein's assumption "without in any way disturbing the system": Bohr rejects Einstein's assumption that the free choice made in the nearby lab does not disturb in any way the system in the faraway lab, even though any such disturbance would have to act essentially instantaneously. That is, in order to rationally counter the Einstein argument Bohr found himself forced to reject Einstein's principle that all causal actions act only forward in time, and no faster than the speed of light. Once that principle is rejected, Einstein's argument collapses.

Bohr's rejection of the demand for the unrestricted applicability of the principle of no-faster-than-light action was certainly no frivolous move. If one examines the quantum state of the entire two-atom system in this correlation experiment then one finds that the effect upon this entire state of the nearby Process 1 action associated with a specified direction of the nearby device is equivalent to the effect upon this state of a faraway Process 1 associated with the parallel direction of the faraway device. That is, instituting the nearby probing action has, within the quantum mechanical description, an instantaneous faraway effect. This effect is not ontologically similar to the causal mechanical effects encountered in classical physics. But there is, nonetheless, within the quantum representation of the physical state of the entire system, a definite effect in the faraway region of the nearby choice of the nearby probing action.

The existence of this instantaneous effect undercuts Einstein's claim that the prediction in question be made without disturbing the system in any way. But the price that Bohr must pay for adopting this way of defeating Einstein's argument is the need to accept the existence of some kind of essentially instantaneous causal actions.

At this point a critic could still maintain that Einstein might be right, namely that: (1), there are no faster-than-light influences of any kind; (2), the predictions of quantum theory in these experiments are valid; and (3), in these correlation-type experiments the values of the unmeasured properties exist simultaneously. However, this possibility was subsequently ruled out by John Bell (1964). Bell's method was simple and direct: he accepted the three demands listed above as premises and derived a mathematical contradiction.

Actually, Bell's assumptions were somewhat stronger than those of Einstein et. al. The latter used the no-faster-than-light action in only one direction: it was assumed that the system in the faraway lab, under either of the two alternative possible conditions that might be chosen there, is not disturbed by the nearby Process 1 choice. Bell, on the other hand, uses this condition in both directions.

Also, Einstein et. al. use settings of just zero and ninety degrees whereas Bell uses also some other angles.

Finally, Bell introduces "hidden variables," which could be some microscopic substructure that controls the macroscopic observables in a way reminiscent of the ideas of classical statistical mechanics, whereas Einstein et. al. deal only with the observable kinds of things, and predictions pertaining to them, without mentioning microscopic variables.

This final difference is not important. Bell's argument can be stripped of "hidden variables", and formulated directly in terms of the macroscopic observable-level concepts used by Einstein and his colleagues. This restructuring was perfomed in (Stapp,1971), and is described in Appendix E.

Bell's conclusion is that if one accepts Einstein's conclusion that the values of the unmeasured properties exist---just as they do in classical physics---and also assumes that the predictions of quantum theory hold in these correlation experiments, then there is a mathematical contradiction with the demand for no-faster-than-light light action. Thus Einstein's position cannot be rationally upheld: it leads to a mathematical contradiction.

Although Einstein's position is thus proved wrong, it does not follow that Bohr is proved right. For if we grant that the predictions of quantum theory are right, the question becomes: which of the other two assumptions in Bell's argument fails; no-faster-than-light action, or definite outcomes of unperformed measurements? Bohr's position is that both of these assumptions must fail, whereas Bell's argument requires merely that one or the other of these two assumptions must fail. Hence Bell's argument does not, by itself, justify Bohr's position that some sort of faster-than-light action is present. However, there is a variation of Bell's argument that accomplishes this task. It is described in Appendix E.

This argument given in Appendix E for a physical failure of the principle of no-faster-than-light action provides essential support for the transition from a pragmatic to an ontological interpretation of von Neumann quantum theory. Without this support it could be argued that the mathematical structure specified by the quantum description of the physical world cannot be interpreted ontologically because that would entail the real existence of essentially instantaneous action at a distance, in violation of the principles of the theory of relativity. However, all the assumptions and conclusions of the argument in Appendix E are fully concordant with the relativistic field-theoretical generalization of the von Neumann theory devised by Tomonaga (1946) and by Schwinger (1951).

In the ontological interpretation everything said before about von Neumann quantum theory is retained, but the evolving mathematical structure now regarded as the physical aspect of what is really happening, instead of merely the mathematical part of a useful computational procedure.

In this ontological construal of von Neumann quantum mechanics the continuous evolution via the local mechanical Process 2 is interrupted from time to time by a "psychophysical" Process 1, which, however, need not now be tied to a human agent, nor even to a biological agent. But then in order to pass from the pragmatic to the ontological interpretation of von Neumann quantum theory a theory of agents needs to be developed. The empirically validated pragmatic theory constitutes the empirically based stepping off point to ontology.

The chief characteristics of this von Neumann ontology are that the physical state of the universe behaves more like a spatially distributed representation of knowledge than like material substance, and that each agent-based psychophysical event has essentially instantaneous distant ramifications in this physical state. These distant ramifications are of a kind intensively examined by Einstein, Bohr, Bell, and many others. They are not some mystical connections lying outside the ken of science, and of scientists, but are rather specific features that are built into orthodox contemporary physics in definite ways that have been extensively studied by physicists, both theoretically and empirically.

Appendix E: Two Proofs.

Bowing to the advice of many non-physicist readers, I have stripped the text of various equations that I thought would be helpful. Although these equations have been replaced by words, this absence of any mathematics from what is basically a mathematical topic must, I fear, leave some readers with a sense of unease: with a residual impression that the arguments exist in some abstruse, recondite plane privy only to physicists.

To dispel this notion I shall give here the proofs of two key results, one pertaining to the non-existence of outcomes of unperformed measurements, the other to the existence of instantaneous action at a distance. The mental effort needed to follow the simple mathematics is surely far less than what is needed to do your taxes.

Bell's Result

In the correlation experiments under consideration here there were, in each of the two labs, for each of the probing actions might be performed there, two possible outcomes. I have been calling these outcomes "Red" and "Green". The first step in the translation into mathematics is to label these two alternative possible outcomes by two different numbers. A convenient choice is the pair of numbers +1 and -1.

Because the predictions of quantum theory are statistical, we need to consider a large set of measurements. So let N be some very large integer, and contemplate an experimental situation in which N essentially identical experiments are performed on N prepared pairs of particles.

The choice of which probing action is undertaken in the first laboratory is specified by an angle θ_1, which specifies the direction associated with the device in the first lab. The choice of which probing action is undertaken in the second laboratory is specified by an angle θ_2, which specifies the direction associated with the device in the second lab.

Let the outcome, +1 or -1, in the first laboratory of the nth experiment be called $R(1, n, \theta_1)$, and let the outcome, +1 or -1, in the second lab of the nth experiment be called $R(2, n, \theta_2)$. The quantities θ_1 and θ_2 specify which probing actions have been chosen in the two labs.

The Einstein-Bohr-Bell debates are centered on a simple prediction of quantum theory, which is that for very large N the following equation is very nearly true:

$$(1/N) \text{ Sum } [R(1, n, \theta_1) \text{ x } R(2, n, \theta_2)] = -\text{Cosine } (\theta_1 - \theta_2). \quad \text{(E1)}$$

Here the sum is over the N different values of n, and x is the symbol for multiplication, which will henceforth be omitted.

Recalling that Cosine (0) = 1, one obtains for the case $\theta_1 = \theta_2$ the perfect (anti) correlation result used by Einstein et. al.: for each n, and each θ,

$R(1, n, \theta) = - R(2, n, \theta)$.

Einstein's conclusion was that, in such correlation experiments, the unmeasured values exist, just as they do in classical physics, but in opposition to the claims of the orthodox quantum physicists.

One cannot, when detecting a given particle, orient the detection device in both of two different ways: for each prepared particle the agent must choose which one of the continuum of possible probing actions will be carried out upon it. But Einstein argued that the assumption that the predictions of quantum theory were correct, together with the assumption that there is no essentially instantaneous action, entails that the values of the properties measured by alternative mutually incompatible probing actions simultaneously exist.

John Bell examined the possibility the Einstein was right: that the unmeasured values exist. But instead of the four particular possibilities considered by Einstein, in which the two alternative possibilities in each lab were specified by angles of zero degrees and ninety degrees, Bell considered other possibilities, and showed that the assumption that the unmeasured values exist leads to a mathematical contradiction.

Suppose, for example, we take the two alternative possible values of θ_1 to be zero and ninety degrees , but the two alternative possible values of θ_2 to be values zero and forty-five degrees. Then we obtain from E1 four mathematically inconsistent equations. They are:

$$(1/N) \text{ Sum } [R(1, n, 0) \times R(2, n, 0)] = - 1. \qquad \text{(E1a)}$$

$$(1/N) \text{ Sum } [R(1, n, 0) \times R(2, n, 45)] = - 1/\sqrt{2}. \qquad \text{(E1b)}$$

$$(1/N) \text{ Sum } [R(1, n, 90) \times R(2, n, 0)] = 0. \qquad \text{(E1c)}$$

$$(1/N) \text{ Sum } [R(1, n, 90) \times R(2, n, 45)] = -1/\sqrt{2}. \qquad \text{(E1d)}$$

To show that these four equations cannot all be true one can use (E1a) to show that $R(1, n, 0) = -R(2, n, 0)$. Hence (E1c) gives

$$(1/N) \text{ Sum } [R(1, n, 90) \times R(1, n, 0)] = 0. \qquad \text{(E2)}$$

Adding (E1b) to (E1d) gives

$$(1/N) \text{ Sum } [(R(1, n, 0) + R(1, n, 90))\, R(2, n, 45)] = -\sqrt{2} . \qquad \text{(E3a)}$$

Because each R is either +1 or -1, this gives

$$(1/N) \text{ Sum } [(R(1, n, 0)R(1, n, 90)+ 1) R(1, n, 90) R(2, n, 45)] = -\sqrt{2} . \tag{E3b}$$

Because a sum of absolute values is greater than or equal to the absolute value of the sum, and every R is either +1 or -1, one can deduce from (E3b), because the absolute value of a product is the product of the absolute values, that

$$(1/N) \text{ Sum } [|R(1, n, 0)R(1, n, 90) +1|] \geq \sqrt{2} . \tag{E4a}$$

Then, because the absolute value of a number that is positive or zero is that number itself, one obtains

$$(1/N) \text{ Sum } [R(1, n, 0)R(1, n, 90) +1] \geq \sqrt{2} . \tag{E4b}$$

Then, using (E2), one obtains

$$1 \geq \sqrt{2} . \tag{E4c}$$

This is false. Hence Einstein's claim that the unmeasured values exist is incompatible not only with the philosophy of quantum theory, but also with the predictions of quantum theory.

This proof treats the equations as if they are exactly true, whereas there are, for large N, small uncertainties that decrease like $1/N^2$. Uncertainties that decrease this fast do not upset the conclusion.

This account of what is, essentially, Bell's result has, unlike Bell's proof (Bell, 1964), avoided any reference to "hidden variables", or to any microscopic concepts. Every mentioned element is macroscopic and potentially observable. (Stapp, 1971, 1979)

The contradiction arises from the combination of three assumptions:
(1) the predictions of quantum theory are valid: (2) values of the unmeasured properties exist: and (3) there are no essentially instantaneous causal actions. The final assumption is needed to justify taking the R's to depend only on which probing action is taken locally, not on which probing action is taken faraway.

This result does not, by itself, show that the validity of the predictions of quantum theory entails the existence of essentially instantaneous action at a distance: the alternative possibility is that the values of the unmeasured properties do not exist.

One argument against this alternative possibility is the argument of Einstein et. al., that if one accepts the predictions of quantum theory and excludes all faster-than-light action, then the values of the unmeasured properties must exist. Because this conclusion is inconsistent with the two assumptions, either the argument or one of these two assumptions must be false. Bohr tried very hard to find a flaw in this argument, but ended up concluding that the no instantaneous action-at-a-distance condition had to be weakened.

Thus combining the result proved above with the arguments of Einstein et. al, and the efforts of Bohr, seems to show the demand that there is no essentially instantaneous action of any kind, must be rejected.

A less circuitous argument supporting this conclusion can be constructed.

<u>Existence of essentially instantaneous actions.</u>

The actual machinery of von Neumann quantum theory involves instantaneous action at a distance. But the issue is whether this feature is merely an artifact of a particular mathematical structure that scientists have created, or is rather a property of nature herself.

The key assumption in the ensuing argument is the idea of fixed past, open future. This idea is compatible with orthodox quantum thinking, and with (the Tomonaga-Schwinger relativistic generalization of) von Neumann quantum theory. The idea is that once an experiment is performed and the outcome is experienced by an observer, this outcome can be considered “fixed”: the outcome can be assumed to be unaltered by how an experimenter in a faraway laboratory chooses, at some later time, to probe a system in his faraway lab. That is, it will be assumed that there is no faster-than-light backward-in-time effect on an already observed outcome in the faraway lab of a choice of probing action made later in the nearby lab. The “past” is fixed, in this sense, while choice about which Process 1 probing actions will presently be undertaken in the nearby laboratory remains open. These conditions are assumed to hold in some frame of reference, for example, the rest frame of the cosmic background radiation.

The exclusion of this kind of backward in time action, entails a faster-than-light effect the earlier choice of probing action in the faraway lab upon the later nearby system, for a certain class experiments called “Hardy-type” experiments. As before the experimenter in each lab can chose between two possible experiments. Let them be called L1 and L2. Let the two possible experiments between which the nearby experimenter can choose be called R1 and R2. Let L1+ represent the statement that LI is chosen and outcome +1 appears. Similarly, L1- represents the assertion that L1 is chosen and outcome -1 appears. The analogous meanings hold for L2, R1, and R2.

Two of the predictions in the Hardy-type experiments are as follows:

(1) If L2 then (R2+ implies L2+).
(2) (L2+ and R1) implies R1-

These combine to give the conclusion

“L2 implies SR” is true.

where

SR = (R2+) implies# (R1 implies R1-)

The meaning of “implies#” is that, in accordance with the assumption of fixed past open future, the implications of the premise (R2+) in the earlier region is not disturbed by changing the later choice in the nearby region from R2 to R1.

Two other predictions are:

(3) If (L1- and R2) then R2+
(4) If (L1- and R1) then sometimes R1+

They (together with the prediction that if L1 is performed the outcome will be – about half the time) entail (Stapp,2004c) that

“L1 implies SR” is false.

So we obtain the result that SR, whose truth or falsity is determined exclusively by possible events in the nearby lab, is true or false according to whether the choice made earlier in the faraway region is L2 or L1. The events in question are all situated at essentially the same time, but in far-apart labs. This result supports Bohr’s contention that if one accepts the validity of the predictions of quantum theory then there must be some sort of action at a distance.

More concretely, this requirement that SR be true or false according to whether L2 or L1 is performed appears to rule out any model or theory in which choices of experimenters can be considered to be “free” variables, and there is no faster-than-light transfer of information.

If one examines the impact of this conclusion upon conceivable models or conceptions of what is really happening in nature at the macroscopic level of experiencable happenings then one is led unavoidably to the conclusion that nature must differ profoundly from the local mechanical ideas of it generated by the postulates and precepts of classical physics.

Appendix F. Science, Free Will, and Morality.

The topic of this appendix is the core topic of the entire book. But it may be useful at this point to distill out the essence of the argument presented in the main text, and to expand upon it, by contrasting it with the principal contemporary alternative approach to the subject.

Advances in the scientific understanding of the connection between our minds and our brains can be expected to have important applications in the treatment of medical and psychological aliments. But an issue of far greater ultimate significance is the impact of the new developments in science on the foundations of moral philosophy. For at the present stage of technological development it is human values that largely control the destiny of our species.

For the past few centuries the main impact of science on moral issues has stemmed from the fact that the concepts of classical physics entail a materialist conception of nature in which each human being is reduced to a collection of cogs in a giant machine. Each of us becomes, according to that view, a puppet whose every act is controlled by the motions of mindless microscopic entities, which themselves are ruled by mechanistic laws. By mechanistic I specifically mean “local deterministic”: each elementary entity, at each instant of time, is located essentially at a point in space, and its immediate future is completely fixed by the physical states of its immediate neighbors. Thus the entire course of world history, from big bang to big crunch (or forever, if the universe lives forever), is fixed already at some early primordial time. Such a mechanistic universe is, according the way most people use the words “free will”, quite devoid of that property. Thus just as we normally say that a mechanical robot lacks free will, so must we say the same of ourselves, insofar as that mechanistic/materialistic world view is accepted. But how can we reconcile this “conclusion of science” with the notion of personal responsibility that normally underlies our moral precepts. That formidable problem is immediately raised by an adoption of the world view of classical physics.

Certain philosophers have resolutely set themselves the task of reconciling the mechanistic materialism of classical physics with the concepts of free will and personal responsibility that underlie our usual precepts of morality. No one has tried harder than Daniel Dennett. In his recent book Freedom Evolves he views much of his 30-year output of books, from his 1984 book Elbow Room, through Consciousness Explained and Darwin’s Dangerous Idea, as the construction of the foundations for his attack on this difficult problem. But, hard as he has tried, people have seemed incapable of properly understanding his main points, which are that “Our minds are just what our brains non-miraculously do,…”(p.xi) and that this premise is compatible with conscious “free will”.

Dennett’s main premise is a simple one, namely the “identity theory” thesis that each conscious thought is the very same thing as some brain activity, and, moreover, that brain activities can be regarded as being---insofar as they bear on these issues---governed by the mechanistic-deterministic laws of nineteenth century classical physics. But a clear understanding of Dennett’s approach seem to be eluding even his most sympathetic readers. He is frustrated (p. 20) with the defection of Steven Pinker, whom he had classified as one of the “responsible, cautious naturalists” like himself, but who, Dennett now says, continues to dally with what he describes as “mysterian doctrines of consciousness”. Dennett is disappointed also with the fact that Robert Wright, who he says gives a fine presentation of most of the ideas that he will be presenting, finds himself unable to fully support Dennett’s “uncompromising materialism”. “Mysterian doctrines of consciousness” appear to be the notion that our conscious thoughts and feelings---those elements of our the streams of consciousness that are the only realities that we actually know---are non-identical to the theoretical inventions of that great alchemist, Isaac Newton; and “uncompromising materialism” appears to mean equating any deviation from nineteenth century classical mechanistic determinism to “defying the laws of physics” (p.1), in spite of the contrary findings of twentieth-century physicists.

Dennett mentions also a book by Richard Dooling that includes an “insightful and accurate” précis of his (Dennett’s) theory of conscious, but then “gets the part about free will dead wrong, just the way that some neuroscientists have done.” (Dennett’s italics.) Thus Dennett, in spite of his intensive long-term effort to explain and defend his ideas, seem to be unable to get even some very serious and like-minded people to correctly understand or agree with him.

So what is going on here? The people Dennett cites seem to be sympathetic with his ideas, but then, in the end, cannot understand him, or disagree with him, or even get key points dead wrong. Why are his ideas so hard to communicate to others?

Dennett (p. 224) quotes Tom Wolfe as noting that he, Dennett, (along with E. O. Wilson and Richard Dawkings) are “presenting elegant arguments” as to why mechanistic materialism does not diminish our self-image, but that the message “is not rippling out to the public. …The conclusion people out beyond the laboratory are drawing is: The fix is in! We are all hardwired! That, and: Don’t blame me! I’m wired wrong!”

Dennett notes (p. 226) that he has already discussed this matter of the status of free will and morality in Consciousness Explained, “but that discussion was obscure and difficult and needs refreshing.” However, the extreme difficulty with Dennett’s position, testified to by the fact that he has written books and books about it yet smart and sympathetic readers still don’t get it, suggests that maybe he is trying, with great cleverness indeed, to prove true a false idea, namely the compatibility of (1), the idea that each of us is a mechanically controlled automaton, with (2), the claim that each of us has a free will that adequately undergirds personal responsibility and our ability to act morally. Dennett says (p. 223) that “I’ve finally come to the conclusion that some people like the confusion.” But the people involved here include intelligent philosophers and scientist who are diligently striving to root out confusion. Why are thirty years of books insufficient to get his thesis across to people such as these?

Dennett's view stems from a basic commitment to the mechanistic determinism of classical physics, coupled with the idea that consciousness is not an idle bystander. These commitments lead naturally to "identity theory", to the idea that consciousness is not a partner with matter, but is, itself, mechanistically deterministic brain-matter in action. His efforts to reconcile this extremely restricted ontology with rational moral philosophy tend to be self contradictory. Thus he extols Daniel Wegner's book The Illusion of Conscious Will by saying (p. 224): "I think Wegner's account of conscious will is the best I have ever seen", but then rejects Wegner's basic claim, and asserts the exact opposite, in a move he downplays as a mere tactical difference. He says that "Wegner thinks it is less misleading, more effective, to say that conscious will is an illusion" but that he, Dennett, thinks the better 'tactic' is "to make the same points by saying that no, free will is not an illusion."

In order to construct a rational moral philosophy concordant with the precepts of classical physics Dennett wants to say that we are mechanistically deterministic beings that enjoy free will. This position requires a twisting of the usual meanings of words that does not seems to fly: even those who generally agree with him seem unable to go along with these tamperings with normal meanings attached to the words he uses.

This commentary on Dennett's efforts to reconcile mechanistic determinism with rational moral philosophy is meant to emphasize that this is not a problem that can be justifiably claimed to have now been well resolved by philosophers. Books and books have been written, it is true, but great volumes of argumentation, followed by repeated re-argumentation, are insufficient, by themselves, and are, instead, a cause for serious skepticism and doubt.

Dennett asserts (p. 14) that his "fundamental perspective is naturalism, the idea that philosophical investigations are not superior to, or prior to, investigations of the natural sciences, but in partnership with those truth-seeking enterprises, and that the proper job for philosophers here is to clarify and unify the often warring perspectives into a single vision of the universe. That means welcoming the bounty of well-won scientific discoveries and theories…" Accordingly, he welcomes the offerings of (neo)Darwinism, but effectively rejects, or rather grossly misunderstands, the equally important offerings of quantum theory.

In his chapter 4 Dennett does consider the idea that the indeterminism of quantum theory might open the door to the entry of a free will that can aid in the construction of a rational moral philosophy. He poses the key question: "How can the indeterminism of quantum physics be harnessed to give us a clear, coherent picture of a human agent exercising this wonderful free will?" But he then poses the question in an essentially different way: "How, exactly, could subatomic indeterminism yield free will?" Then, rather than considering quantum theory itself, he goes on at great length to discredit a model constructed by Robert Kane, who introduces a random element of indeterminism to break the absolute determinism of classical physics in the hope of thereby exploiting quantum theory to open the way to a satisfactory concept of free will. However, the replacement of conscious choices by random or whimsical choices certainly cannot provide a rational basis for morality. What is needed is not the injection into human behavior of pure whimsy. It is rather what quantum theory so beautifully and adequately supplies, namely the suppression of chance and randomness by choices stemming from a process arising, not from either mindless motions atoms or meaningless bits of noise, but rather from the wholeness, the meanings, and the physical efficacy of our conscious thoughts.

Later on (p. 223) Dennett asserts that he believes there is a morally important non-supernatural free will, but that it is "just not what you probably thought it was." But what does the scientifically knowledgeable reader think a non-supernatural free will is?

Nature certainly contains non-supernatural thoughts and feelings: they are non-illusory real parts of the natural world. Both Dennett and quantum physics agree that they are causally efficacious, and are in some sense "free". But it is Dennett's own pre-judgment, not contemporary science, that insists that each of these components of a stream of consciousness is identical to some mechanistic material processes. It is his rigid commitment to the ideology of classical physics that is the basic source of the difficulties Dennett encounters: it is that choice that foists upon him the impossible task of showing that mechanically deterministic automata possess conscious free wills that can underlie rational moral philosophy.

The bounty offered by quantum theory is not the introduction of meaningless whimsy. It is the introduction of immaterial causes. The indeterminism introduce by quantum theory comes in two forms. One consists of the random "choices on the part of nature". These conform to certain statistical laws linked to the quantum theoretical structure that replaces the material structure postulated by classical physics. The other form of indeterminism stems from a physically efficacious conscious will that is "free" in the sense that it is not fixed by any yet-known, or mechanical, laws Our consciousness-based choices are important real elements in quantum theory: the whole theory is built around these conscious "free" choices on the part of human agents. They are not supernatural. Mathematical representations, formed in our endlessly creative imaginations, of some assumed-to-exist objective world 'out there' can come and go, and can morph in strange ways. But our choices about how we act will probably remain a stable element of science, because we can, by acting in diverse ways and observing the feedbacks, discover many more aspects of nature than we can by mere passive witnessings. Our consciously activated probing actions are fundaments of human life, and of both science in general and quantum theory in particular.

Dennett correctly poses the key question: “How can the indeterminism of quantum physics be harnessed to give us a clear, coherent picture of a human agent exercising this wonderful free will?” The basic thrust of the present book has been to give a specific answer to this question, together with the background needed to understand that answer. The answer in brief is that the quantum Zeno effect provides a nonlocal consciousness-driven process that permits a person’s conscious volitional choices to exercise significant control over the activities of his or her own brain.

Left unaddressed, however, was the task of specifying the causal origin of these conscious choices.

Pursuit of this important question takes us beyond the realm of contemporary physical theory. I have taken great pains to keep the content of this book securely in line with orthodox contemporary physics, by which I mean the main-line Copenhagen interpretation, extend by the work of John von Neumann to cover the activities of human brains

But now, in this final appendix, with a strong advisory that I am venturing into a realm of speculative philosophy, where contemporary physics provides no orthodoxy, I shall tackle this remaining issue in a way that appeals to my own personal intuitions. No claim is made that these speculations represent the best thinking of physicists or of philosophers. They are simply my own best guesses, for what they are worth, unsupported by any new confirming data. Still, educated guesses, compatible with what is already known, are an important element of science.

The issue here is the causes of the conscious choices made by the human agents about how they will act. My own prejudice is that nothing happens without a sufficient cause: there is no pure whimsy and, moreover, the next step in basic science will embrace the idea of a process of a “coming into being” that converts “potentialities” into “actualities”, as suggested by Heisenberg. But nothing definite can come into being simply “out of the blue”. So these choices must have some reason to be what they turn out to be, instead of something else. Indeed, we seem to be at least dimly aware of some of our reasons for making the choices that we make, and psychiatrists---and more recently neuroscientists---have made claims about such cause that are not completely at odds with empirical evidence. How can such causes be understood in a way concordant with quantum theory?

I begin with the supposition that the “conscious choices on the part of the human agents” that quantum orthodoxy is built upon do indeed exist (or at least that a rationally coherent science-based understanding of the structure of human experience is possible in which these choices do exist) and that these volitional choices have necessary and sufficient causes, i.e., have reasons to be what they turn out to be, instead of something else. In other words, I am starting with orthodox contemporary quantum theory, and trying to complete it in a way that makes it part of an ontology that explains the nature of the factors that determine the “free choices” of orthodox contemporary physics.

I assume that our choices do not pop out of nothingness, and are in fact influenced by our prior experiences. This influence, or correlation, must be accounted for by a complete theory of nature. Quantum theory is not a complete theory of nature, because it does not explain the causes of our so-called “free choices”.

The mathematical structure of quantum theory asserts that whereas the evolution of the quantum (i.e., physical) state of a system in accordance with von Neumann’s Process 2 is essentially mechanistic (i.e., locally deterministic), the interventions of Process 1 are essentially non-mechanistic (i.e., nonlocal): the effect of each such intervention acts instantaneously over an extended spatial region, and it can have, moreover, instantaneous (i.e., faster than light) subtle effects far away. Each Process 1 intervention represents an “observation” or “actualization of a particular potentiality from amongst the multitude specified by the prior quantum state”.

The simplest way to impose a modicum of regularity on this structure is to suppose that there is a variety of elementary properties that can be combined in a variety of possible ways in a Process 1 event. Each such event “occurs” at some instant of time and covers some fixed region of three-dimensional space. Some of the elementary properties involved in such an event may be completely describable in terms of mathematical properties localized essentially at space-time points, whereas some elementary properties can combine to give, for example, the experiential quality of greenness, or the sorrow at the death of a beloved companion. These latter qualities are conceptualized in psychological or experiential terms. That is, certain elementary properties can combine to give experiences of the kind that populate our streams of conscious experiences.

Each Process 1 event, or happening, or actual occasion, is a gathering together, or prehension, of a generally large number of properties in some fixed region of space at some instant of time. Each such event fixes, or actualizes, in that region, a certain combination of properties that serve as potentialities for future events. Each event re-actualizes, in a newly combined novel way, various properties---or parts of properties---previously actualized in certain prior events.

This general structure is very similar to the structure found in contemporary physics, where the dynamics can be understood as built out of a series of “scattering events”, each of which gathers together and combines certain physical properties, drawn from a certain set of prior scattering events, and then serves as a source of properties that can be drawn upon by subsequent scattering events. One key difference between classical physics and quantum physics is that in the former the entire sequence of happenings is fixed by initial conditions, whereas in the latter the physically describable constraints permit, for any possible initial condition, a huge blur of subsequent possibilities: the physically described constraints specify only a collection of subsequent future possibilities, each with a statistical weight. They do not fix what actually happens, or is experienced by observers. Another process, Process 1, is needed to specify what actually happens. It involves properties not entering into classical dynamics.

During the twentieth century theoretical physics has generated many important properties beyond the simple space-time and energy-momentum properties identified and used in classical physics. These new properties are "internal" properties of particles that do not fix where the particle is, or its velocity, or its charge or energy, but which, however, can combine to form important macroscopic (i.e., large-scale) properties. Physical theories certainly need not be limited to the use of properties identified and applied in classical physics.

There are two big differences between the classical and quantum models. The first is nonlocality. The Process 1 reduction (or actualization) event is nonlocal, in the sense that it happens instantaneously over an extended region, and integrates the various properties brought into that region from certain prior events. Process 2, on the other hand, is a local process. However, it generates only "potentialities" for what might or can happen, not a definite fixing of what actually does happen. The Potentialities, like their classical counterparts, evolve according to local laws, but the actualities are determined by a process that is not locally deterministic: it is not "mechanical", in my terminology.

The second big difference is this distinction between (1), the potentialities, which are governed---between the interventions of the Process 1 actions---by purely physical laws, and (2), the actualities which are created by the Process 1 interventions, which can involve experiential qualities. The physically described features governed by Process 2 specify only the necessary conditions for a possible event, in the sense of a statistical weighting of the various possibilities, whereas experiential or proto-experiential qualities enter into the sufficient conditions for the occurrence of some particular one of the many physically allowed events. In the classical theory the necessary and sufficient conditions for an actual event to occur are not separated in this way.

Each quantum Process 1 event draws upon past experiences as the grist from which it forms its own experiential nature. Our human experiences are examples of the experiential aspects of Process 1 events. But they are very complex examples, associated with very complex physical systems, which have evolved to take advantage of the existence and properties of this process. But Process 1 events can occur, and presumably do occur, also in conjunction with far simpler physical systems. In these physically simpler cases the "experiential" aspect can be something far simpler than anything we human beings would recognize and describe as an experience.

This brief sketch does not describe or constitute a physical theory: it is merely a general outline of how quantum theory might someday be extended in a natural rational way from its present pragmatic form into a coherent idea of how Nature actually works. It is a rough blueprint for a future endeavor. I include it here only to dispel the idea that we must be dealing with some super-natural phenomena that are anthropocentrically tied to human beings, or to biological entities, or that "defy the laws of physics". We are dealing, rather, with a real aspect of nature that is omitted from classical physics, but that constitutes an essential constituent of the actual world in which live and consciously act.

This loose sketch of a conceivable quantum ontology is in overall general agreement with the basic ideas of Alfred North Whitehead (1929/1978). Many physicists, including Abner Shimony (1993), Rudolf Haag (1996) and myself (Stapp, 1979), have noted the suitability of Whitehead's ideas as a foundation for an ontological completion of quantum theory. But the incorporation of such ontological speculations into empirically backed science awaits the arrival of secure pertinent data.

The morality that emerges from science will depend upon what science reveals about our connection to the universe that sustains us, and upon our judgments about how to orient ours lives in relation to it.
But an appreciation of the established fact that the natural world enjoys a deep interconnectedness that goes far beyond what the precepts of classical physics can permit, and that the course of physical events can, according to contemporary physics, be influenced by the intervention of physically effective personal actions that stem from our conscious reflections on the meanings of our actions, arms us with an image of ourselves that allows us to be far more significant parts of the scheme of things than the classical-physics-based image of ourselves as lonely bits of protoplasm, spawned by some freakish accidents of nature, and existing only because we serve as a vehicles for the survival of our genes. That impoverished self-image leads rationally to the meaningless of it all, and, inevitably, to the downward spiral of humanity into a society of machines that is even now being erected by zealous seekers of a simplified and more controllable social order that will bring our lives into alignment with the "established" classical-physics-based mechanical conception of what we human beings are.